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ACM RA-2005

Appendix RA – Certification of Alternative Calculation Method

Energy Efficiency Standards for Residential Buildings, Sections 150 to 152

I, ____ (name), certify that this alternative calculation method (ACM), ____ (name of ACM), version number ____________, dated ____________________, developed by, _______________________________ (personnel or company), _______________________________ (address) _______________________________ (city, state) ________ (zip), passes all of the ACM tests and gives results that are reliable and accurate when used for calculating custom budgets and annual energy use estimates to comply with CEC (California Energy Commission) regulations, subject to the fixed and restricted assumptions specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2005~~1~~ Energy Efficiency Standards for Residential Buildings*, and the fixed and restricted inputs specified in the manuals describing the use of this method (Users Manual and Compliance Supplement thereto). I certify that the calculation of energy use in buildings, following the instructions in the manuals, and using accurate and complete plans and specifications for a building will achieve reliable and accurate energy analysis results with this ACM. Moreover, the calculations are verifiable when modeling the same building and accurately applying the fixed and restricted assumptions and inputs mentioned above. I further certify that all variables used by the program that are not subject to ready verification in the plans and specifications or that are subject to occupant use are either fixed, carefully restricted, or defaulted in this ACM.

I also certify that the inputs, default values, and assumptions specified for compliance runs in the manuals, and used in the accompanying application for the CEC residential ACM approval, are consistent with the inputs, default values, and assumptions specified by the CEC in the *Alternative Calculation Method (ACM) Approval Manual for the 2005~~1~~ Energy Efficiency Standards for Residential Buildings* for use when generating standard design budgets and annual energy use estimates. I also certify that all specific inputs, variables, and assumptions needed to achieve the accuracy required to pass the capability tests in the *ACM Approval Manual* are either not subject to user variation, are defaulted to the values used for compliance, or are clearly specified as restricted or required inputs in the manuals for the ACM. In addition, the manuals clearly indicates that an easily verified list of the actual values of any such variables used for performance approach compliance which are subject to programmatic or user variation are to be included with the compliance documentation supplied by a building permit applicant to the enforcement agency. In summary, I also certify that the results of this alternative calculation method as specified in the manuals for the ACM in conjunction with an accurate and adequate set of plans and specifications for a building are not subject to significant variation by the manipulation of unrestricted user specified inputs that are difficult or impossible to verify.

In certifying the reliability and accuracy of this ACM, I certify that the results of this ACM's calculations, algorithms and assumptions are open to inspection by any individual or State entity, that this ACM may be challenged for its validity and accuracy as specified by the ACM Approval Manual, and that if challenged, I will prepare an adequate response or face possible withdrawal of ACM approval.

This certification is based upon the tests and requirements specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2005~~1~~ Energy Efficiency Standards for Residential Buildings,* and upon personal knowledge and experience with the use of this alternative calculation method.

Signed Date Title

Space Conditioning Tests (SC)

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test SC00 – Basecase Simulations

Enter the TDV energy for the standard design and the proposed design – values should match.

Test Label	TDV Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SC00A01			
SC00A02			
SC00A03			
SC00A04			
SC00A05			
SC00A06			
SC00A07			
SC00A08			
SC00A09			
SC00A10			
SC00A11			
SC00A12			
SC00A13			
SC00A14			
SC00A15			
SC00A16			
SC00B01			
SC00B02			
SC00B03			
SC00B04			
SC00B05			
SC00B06			
SC00B07			
SC00B08			
SC00B09			
SC00B10			
SC00B11			
SC00B12			
SC00B13			
SC00B14			
SC00B15			
SC00B16			

Test SC01 – SEER vs. AFUE

	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC01A03						
SC01A09						
SC01A12						
SC01A14						
SC01A16						

Test SC02 – Ceiling U-factor vs. South Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC02A03						
SC02A09						
SC02A12						
SC02A14						
SC02A16						

Test SC03 – Wall U-factor vs. West Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC03A03						
SC03A09						
SC03A12						
SC03A14						
SC03A16						

Test SC04 – Slab F-factor vs. North Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC04A12						
SC04A14						
SC04A16						

Test SC05 – Fenestration Type vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC05A03						
SC05A09						
SC05A12						
SC05A14						
SC05A16						

Test SC06 – Fenestration Type vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC06A03						
SC06A09						
SC06A12						
SC06A14						
SC06A16						

Test SC07 – Exposed Thermal Mass vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC07A12						
SC07A14						
SC07A16						

Test SC08 – Exposed Thermal Mass vs. West Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC08A03						
SC08A09						
SC08A12						
SC08A14						
SC08A16						

Test SC09 – Exposed Thermal Mass vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC09A03						
SC09A09						
SC09A12						
SC09A14						
SC09A16						

Test SC10 – Exposed Thermal Mass vs. East Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		East Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC10A03						
SC10A09						
SC10A12						
SC10A14						
SC10A16						

Test SC11 – South Overhangs vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC11A03						
SC11A09						
SC11A12						
SC11A14						
SC11A16						

Test SC12 – Building Envelope Sealing vs. Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC12A03						
SC12A09						
SC12A12						
SC12A14						
SC12A16						

Test SC13 – Building Envelope Sealing and Mechanical Ventilation vs. Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC13A03						
SC13A09						
SC13A12						
SC13A14						
SC13A16						

Test SC14 – Construction Quality vs. AFUE

	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC14A03						
SC14A09						
SC14A12						
SC14A14						
SC14A16						

Test SC15 – Cool Roofs/Radiant Barrier vs. SEER

	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC15A09						
SC15A12						
SC15A14						

Test SC16 – Natural Ventilation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC16A09						
SC16A12						
SC16A14						

Test SC17 – Duct Leakage vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC17A03						
SC17A09						
SC17A12						
SC17A14						
SC17A16						

Test SC18 – Duct Surface Area vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC18A03						
SC18A09						
SC18A12						
SC18A14						
SC18A16						

Test SC19 – Duct Location vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC19B09						
SC19B12						
SC19B14						

Test SC20 – Duct Insulation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC20A09						
SC20A12						
SC20A14						

Test SC21 – Energy Efficiency Ratio vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC21A09						
SC21A12						
SC21A14						

Test SC22 – TXV/Charge Testing vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC22A09						
SC22A12						
SC22A14						

Test SC23 – Airflow Across Evaporator Coil vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC23A09						
SC23A12						
SC23A14						

Test SC24 – Air Conditioner Fan Power vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC24A09						
SC24A12						
SC24A14						

Test SC25 – Electric Heat vs. Fenestration U-Factor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC25A03						
SC25A09						
SC25A12						
SC25A14						
SC25A16						

Test SC26 – Side Fins

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC26A09						
SC26A12						
SC26A14						

Standard Design Tests (SD)

Test SD01 – Single-Family Slab-on-Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD01C01					
SD01C02					
SD01C03					
SD01C04					
SD01C05					
SD01C06					
SD01C07					
SD01C08					
SD01C09					
SD01C10					
SD01C11					
SD01C12					
SD01C13					
SD01C14					
SD01C15					
SD01C16					

Test SD02 – Single-Family Raised Floor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD02D01					
SD02D02					
SD02D03					
SD02D04					
SD02D05					
SD02D06					
SD02D07					
SD02D08					
SD02D09					
SD02D10					
SD02D11					
SD02D12					
SD02D13					
SD02D14					
SD02D15					
SD02D16					

Test SD03 – Multi-Family Slab on Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD03E01					
SD03E02					
SD03E03					
SD03E04					
SD03E05					
SD03E06					
SD03E07					
SD03E08					
SD03E09					
SD03E10					
SD03E11					
SD03E12					
SD03E13					
SD03E14					
SD03E15					
SD03E16					

Test SD04 – Neutral Variable Test: Window Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD04A03					
SD04A09					
SD04A12					
SD04A14					
SD04A16					

Test SD05 – Neutral Variable Test: Wall Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD05A03					
SD05A09					
SD05A12					
SD05A14					
SD05A16					

Additions and Alterations Tests

Test AA01 – Baseline Simulations

Label	TDV Energy (kBtu/ft²/y)		ACM Filenames
	Standard Design	Proposed Design	
AA01E03			
AA01E09			
AA01E12			
AA01E14			
AA01E16			

Test AA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
AA02E03						
AA02E09						
AA02E12						
AA02E14						
AA02E16						

Test AA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
AA02E03						
AA02E09						
AA02E12						
AA02E14						
AA02E16						

Test EA01 – Baseline

Label	TDV Energy (kBtu/ft²/y)		ACM Filenames
	Standard Design	Proposed Design	
EA01E03			
EA01E09			
EA01E12			
EA01E14			
EA01E16			

Test EA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA02E03						
EA02E09						
EA02E12						
EA02E14						
EA02E16						

Test EA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA02E03						
EA02E09						
EA02E12						
EA02E14						
EA02E16						

Water Heating Tests

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test WH00 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
WH00C01			
WH00C02			
WH00C03			
WH00C04			
WH00C05			
WH00C06			
WH00C07			
WH00C08			
WH00C09			
WH00C10			
WH00C11			
WH00C12			
WH00C13			
WH00C14			
WH00C15			
WH00C16			
WH00E01			
WH00E02			
WH00E03			
WH00E04			
WH00E05			
WH00E06			
WH00E07			
WH00E08			
WH00E09			
WH00E10			
WH00E11			
WH00E12			
WH00E13			
WH00E14			
WH00E15			
WH00E16			

Test WH01 – Gas Storage vs. Electric Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH01C03						
WH01C09						
WH01C12						
WH01C14						
WH01C16						
WH01E03						
WH01E09						
WH01E12						
WH01E14						
WH01E16						

Test WH02 – Gas Storage vs. Electric Instantaneous Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH02C03						
WH02C09						
WH02C12						
WH02C14						
WH02C16						
WH02E03						
WH02E09						
WH02E12						
WH02E14						
WH02E16						

Test WH03 – Pipe Insulation on All Lines

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH03C03						
WH03C09						
WH03C12						
WH03C14						
WH03C16						

Test WH04 – Recirculation Control

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH04E03						
WH04E09						
WH04E12						
WH04E14						
WH04E16						

Test WH05 –Large Gas Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH05E03						
WH05E09						
WH05E12						
WH05E14						
WH05E16						

Test WH06 – Recirculation Piping Insulation

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH06E03						
WH06E09						
WH06E12						
WH06E14						
WH06E16						

Test WH07 – Number of Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH07C03						
WH07C09						
WH07C12						
WH07C14						
WH07C16						

Test WH08 – Pump Controls

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH08E03						
WH08E09						
WH08E12						
WH08E14						
WH08E16						

Water Heating Neutral Variable Tests (WD)

Test WD01 – Increase House Size to 2500ft^2

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD01C03					
WD01C09					
WD01C12					
WD01C14					
WD01C16					

Test WD02 – Increase House Size to 3500ft^2

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD02C03					
WD02C09					
WD02C12					
WD02C14					
WD02C16					

Test WD03 – Increase Recirculation Piping Length

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD03D03					
WD03D09					
WD03D12					
WD03D14					
WD03D16					

Test WD04 – Change Recirculation Pipe Location

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD04D03					
WD04D09					
WD04D12					
WD04D14					
WD04D16					

Test WD05 – Change to Individual Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD05D03					
WD05D09					
WD05D12					
WD05D14					
WD05D16					

Optional Capabilities Tests (OC)

Test OC01 – Dedicated Hydronic Heating

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC01A03						
OC01A09						
OC01A12						
OC01A14						
OC01A16						

Test OC02 – Combined Hydronic, Gas Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC02A03						
OC02A09						
OC02A12						
OC02A14						
OC02A16						

Test OC03 – Combined Hydronic, Electric Resistance Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC03A03						
OC03A09						
OC03A12						
OC03A14						
OC03A16						

Test OC04 – Combined Hydronic, Heat Pump Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC04A03						
OC04A09						
OC04A12						
OC04A14						
OC04A16						

Test OC05 – Control Vent Crawlspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC05B03						
OC05B 09						
OC05B 12						
OC05B 14						
OC05B 16						

Test OC06 – Zonal Control

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC06A03						
OC06A09						
OC06A12						
OC06A14						
OC06A16						

Test OC07 – Attached Sunspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC07A03						
OC07A09						
OC07A12						
OC07A14						
OC07A16						

Test OC08 – Exterior Mass Walls

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Wall R-Value Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC08A03						
OC08A09						
OC08A12						
OC08A14						
OC08A16						

Test OC09 – Gas Engine Driven Cooling

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC09A03						
OC09A09						
OC09A12						
OC09A14						
OC09A16						

Test OC10 – Gas Absorption Cooling

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC10A03						
OC10A09						
OC10A12						
OC10A14						
OC10A16						

Solar Systems Tests (SS)

Test SS01 – Solar System with Electric Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS01A03			
SS01A09			
SS01A12			
SS01A14			
SS01A16			

Test SS02 – Solar System with Gas Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS02A03			
SS02A09			
SS02A12			
SS02A14			
SS02A16			

Test SS03 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS03F01			
SS03F02			
SS03F03			
SS03F04			
SS03F05			
SS03F06			
SS03F07			
SS03F08			
SS03F09			
SS03F10			
SS03F11			
SS03F12			
SS03F13			
SS03F14			
SS03F15			
SS03F16			

Test SS04– Collector Orientation

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS04F03			
SS04F09			
SS04F12			
SS04F14			
SS04F16			

Test SS05– Collector Slope

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS05F03			
SS05F09			
SS05F12			
SS05F14			
SS05F16			

Test SS06– Collector Performance

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS06F03			
SS06F09			
SS06F12			
SS06F14			
SS06F16			

Test SS07– Collector Area

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS07F03			
SS07F09			
SS07F12			
SS07F14			
SS07F16			

Test SS08– Storage Tank Size

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS08F03			
SS08F09			
SS08F12			
SS08F14			
SS08F16			

Test SS10– Circulation Pump

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS10F03			
SS10F09			
SS10F12			
SS10F14			
SS10F16			

Test SS11– Freeze Control

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS11F03			
SS11F09			
SS11F12			
SS11F14			
SS11F16			

~~**Space Conditioning Test 1**~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~01A00~~				~~01A01~~			
~~02A00~~				~~02A01~~			
~~03A00~~				~~03A01~~			
~~04A00~~				~~04A01~~			
~~05A00~~				~~05A01~~			
~~06A00~~				~~06A01~~			
~~07A00~~				~~07A01~~			
~~08A00~~				~~08A01~~			
~~09A00~~				~~09A01~~			
~~10A00~~				~~10A01~~			
~~11A00~~				~~11A01~~			
~~12A00~~				~~12A01~~			
~~13A00~~				~~13A01~~			
~~14A00~~				~~14A01~~			
~~15A00~~				~~15A01~~			
~~16A00~~				~~16A01~~			
~~03B00~~				~~03B01~~			
~~09B00~~				~~09B01~~			
~~12B00~~				~~12B01~~			
~~14B00~~				~~14B01~~			
~~16B00~~				~~16B01~~			

~~**Space Conditioning Test 2**~~

~~Basecase Building~~	~~Prototype Variation~~						
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~01A00~~				~~01A02~~			
~~02A00~~				~~02A02~~			
~~03A00~~				~~03A02~~			
~~04A00~~				~~04A02~~			
~~05A00~~				~~05A02~~			

~~06A00~~				~~06A02~~			
~~07A00~~				~~07A02~~			
~~08A00~~				~~08A02~~			
~~09A00~~				~~09A02~~			
~~10A00~~				~~10A02~~			
~~11A00~~				~~11A02~~			
~~12A00~~				~~12A02~~			
~~13A00~~				~~13A02~~			
~~14A00~~				~~14A02~~			
~~15A00~~				~~15A02~~			
~~16A00~~				~~16A02~~			
~~03B00~~				~~03B02~~			
~~09B00~~				~~09B02~~			
~~12B00~~				~~12B02~~			
~~14B00~~				~~14B02~~			
~~16B00~~				~~16B02~~			

~~Space Conditioning Test 3~~

~~Reduce ceiling U-value and increase south glass~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A03~~			
~~09A00~~				~~09A03~~			
~~12A00~~				~~12A03~~			
~~14A00~~				~~14A03~~			
~~16A00~~				~~16A03~~			

~~Space Conditioning Test 4~~

~~Reduce wall U-value and increase west glass~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A04~~			
~~09A00~~				~~09A04~~			
~~12A00~~				~~12A04~~			
~~14A00~~				~~14A04~~			

~~16A00~~				~~16A04~~			

~~Space Conditioning Test 5~~

~~Add slab insulation and increase north glass~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A05~~			
~~09A00~~				~~09A05~~			
~~12A00~~				~~12A05~~			
~~14A00~~				~~14A05~~			
~~16A00~~				~~16A05~~			

~~**Space Conditioning Test 6**~~

~~Reduce glazing U-value and add north glass~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A06~~			
~~09A00~~				~~09A06~~			
~~12A00~~				~~12A06~~			
~~14A00~~				~~14A06~~			
~~16A00~~				~~16A06~~			

~~**Space Conditioning Test 7**~~

~~Increase glazing U-value and reduce glass area on all orientations~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A06~~			
~~09A00~~				~~09A07~~			
~~12A00~~				~~12A07~~			
~~14A00~~				~~14A07~~			
~~16A00~~				~~16A07~~			

~~**Space Conditioning Test 8**~~

~~Increase exposed mass and increase south glass area~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A08~~			
~~09A00~~				~~09A08~~			
~~12A00~~				~~12A08~~			
~~14A00~~				~~14A08~~			
~~16A00~~				~~16A08~~			

~~Space Conditioning Test 9~~

~~Increase exposed mass and increase west glass area~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A09~~			
~~09A00~~				~~09A09~~			
~~12A00~~				~~12A09~~			
~~14A00~~				~~14A09~~			
~~16A00~~				~~16A09~~			

~~Space Conditioning Test 10~~

~~Increase exposed mass and increase north glass area~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A10~~			
~~09A00~~				~~09A10~~			
~~12A00~~				~~12A10~~			
~~14A00~~				~~14A10~~			
~~16A00~~				~~16A10~~			

~~Space Conditioning Test 11~~

~~Increase exposed mass and increase east glass area~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A11~~			
~~09A00~~				~~09A11~~			
~~12A00~~				~~12A11~~			
~~14A00~~				~~14A11~~			
~~16A00~~				~~16A11~~			

~~Space Conditioning Test 12~~

~~Reduce exposed thermal mass, add exterior shading and increase west glass~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A12~~			
~~09A00~~				~~09A12~~			
~~12A00~~				~~12A12~~			
~~14A00~~				~~14A12~~			
~~16A00~~				~~16A12~~			

~~Space Conditioning Test 13~~

~~Increase exposed thermal mass, add better interior shading and increase south glass~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A13~~			
~~09A00~~				~~09A13~~			
~~12A00~~				~~12A13~~			
~~14A00~~				~~14A13~~			
~~16A00~~				~~16A13~~			

~~Space Conditioning Test 14~~

~~Add south overhang and increase south glass~~

~~Basecase Building~~				~~Prototype Variation~~			
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A14~~			
~~09A00~~				~~09A14~~			
~~12A00~~				~~12A14~~			
~~14A00~~				~~14A14~~			
~~16A00~~				~~16A14~~			

~~Space Conditioning Test 15~~

~~Move ducts to conditioned space and increase glass on all orientations~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A15~~			
~~09A00~~				~~09A15~~			
~~12A00~~				~~12A15~~			
~~14A00~~				~~14A15~~			
~~16A00~~				~~16A15~~			

~~Water Heating Tests~~

~~Enter the calculated values~~

~~Climate Zone~~	~~D~~	~~E~~	~~F~~	~~G~~	~~H~~	~~I~~	~~J~~
~~Energy Budget~~							
~~Standard~~							
~~POU/HWR~~							
~~Pipe Insulation~~							
~~Recirc/NoControl~~							
~~Recirc/Timer~~							
~~Recirc/Demand~~							
~~Recirc/Time+Temp~~							
~~Recirc/Temp~~							
~~Parallel Piping~~							

~~Custom Budget Space Conditioning 31~~

~~Gas heated slab floor building~~

	~~Basecase Building~~				~~Standard Design Equivalent~~		
	~~(from custom budget column)~~				~~(from proposed design column)~~		
~~Label~~		~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Heating~~	~~Total~~
~~01C31~~				~~01C31C~~			
~~02C31~~				~~02C31C~~			
~~03C31~~				~~03C31C~~			
~~04C31~~				~~04C31C~~			
~~05C31~~				~~05C31C~~			
~~06C31~~				~~06C31C~~			
~~07C31~~				~~07C31C~~			
~~08C31~~				~~08C31C~~			
~~09C31~~				~~09C31C~~			
~~10C31~~				~~10C31C~~			
~~11C31~~				~~11C31C~~			
~~12C31~~				~~12C31C~~			
~~13C31~~				~~13C31C~~			
~~14C31~~				~~14C31C~~			
~~15C31~~				~~15C31C~~			
~~16C31~~				~~16C31C~~			

~~Custom Budget Space Conditioning 32~~

~~Gas heated raised floor building~~

	~~Basecase Building~~				~~Standard Design Equivalent~~		
	~~(from custom budget column)~~				~~(from proposed design column)~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~01C32~~				~~01C32C~~			
~~02C32~~				~~02C32C~~			
~~03C32~~				~~03C32C~~			
~~04C32~~				~~04C32C~~			
~~05C32~~				~~05C32C~~			
~~06C32~~				~~06C32C~~			
~~07C32~~				~~07C32C~~			

~~08C32~~				~~08C32C~~			
~~09C32~~				~~09C32C~~			
~~10C32~~				~~10C32C~~			
~~11C32~~				~~11C32C~~			
~~12C32~~				~~12C32C~~			
~~13C32~~				~~13C32C~~			
~~14C32~~				~~14C32C~~			
~~15C32~~				~~15C32C~~			
~~16C32~~				~~16C32C~~			

~~Custom Budget Space Conditioning 33~~

~~Electric heated slab floor building~~

~~)~~ ~~Label~~	~~Basecase Building~~ ~~(from custom budget column~~ ~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Standard Design Equivalent~~ ~~(from proposed design column)~~ ~~Heating~~	~~Cooling~~	~~Total~~
~~01C33~~	________	________	________	~~01C33C~~	________	________	________
~~02C33~~	________	________	________	~~02C33C~~	________	________	________
~~03C33~~	________	________	________	~~03C33C~~	________	________	________
~~04C33~~	________	________	________	~~04C33C~~	________	________	________
~~05C33~~	________	________	________	~~05C33C~~	________	________	________
~~06C33~~	________	________	________	~~06C33C~~	________	________	________
~~07C33~~	________	________	________	~~07C33C~~	________	________	________
~~08C33~~	________	________	________	~~08C33C~~	________	________	________
~~09C33~~	________	________	________	~~09C33C~~	________	________	________
~~10C33~~	________	________	________	~~10C33C~~	________	________	________
~~11C33~~	________	________	________	~~11C33C~~	________	________	________
~~12C33~~	________	________	________	~~12C33C~~	________	________	________
~~13C33~~	________	________	________	~~13C33C~~	________	________	________
~~14C33~~	________	________	________	~~14C33C~~	________	________	________
~~15C33~~	________	________	________	~~15C33C~~	________	________	________
~~16C33~~	________	________	________	~~16C33C~~	________	________	________

~~Space Conditioning Ducts Test 34~~

~~Duct designed to meet ACCA Manual D with sealed and tested ducts~~

~~Label~~	~~Basecase Building~~ ~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Prototype Variation~~ ~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~	________	________	________	~~03A34~~	________	________	________
~~09A00~~	________	________	________	~~09A34~~	________	________	________
~~12A00~~	________	________	________	~~12A34~~	________	________	________
~~14A00~~	________	________	________	~~14A34~~	________	________	________
~~16A00~~	________	________	________	~~16A34~~	________	________	________

~~Space Conditioning Ducts Test 35~~

~~Sealed and tested ducts~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A35~~			
~~09A00~~				~~09A35~~			
~~12A00~~				~~12A35~~			
~~14A00~~				~~14A35~~			
~~16A00~~				~~16A35~~			

~~Space Conditioning Ducts Test 36~~

~~Ducts and air handler in conditioned space with sealed and tested ducts~~

~~03A00~~				~~03A36~~			
~~09A00~~				~~09A36~~			
~~12A00~~				~~12A36~~			
~~14A00~~				~~14A36~~			
~~16A00~~				~~16A36~~			

~~Addition Plus Existing Test 37~~

~~Mandatory minimum R-19 ceiling, R-13 walls in addition~~

~~03A00~~				~~03A37~~			
~~09A00~~				~~09A37~~			
~~12A00~~				~~12A37~~			
~~14A00~~				~~14A37~~			
~~16A00~~				~~16A37~~			

~~Addition Plus Existing Test 38~~

~~Existing and addition roof meets Package D, change west facing glazing~~

~~03A00~~				~~03A38~~			
~~09A00~~				~~09A38~~			
~~12A00~~				~~12A38~~			
~~14A00~~				~~14A38~~			
~~16A00~~				~~16A38~~			

~~Space Cooling SSEER Test 39~~

~~Split system, 12 SEER, TXV, sealed and tested ducts, and ACCA Manual D duct design~~

~~03A00~~				~~03A39~~			
~~09A00~~				~~09A39~~			
~~12A00~~				~~12A39~~			
~~14A00~~				~~14A39~~			
~~16A00~~				~~16A39~~			

~~Space Cooling SSEER Test 40~~

~~Split system, 10.5 SEER and TXV~~

~~03A00~~				~~03A40~~			
~~09A00~~				~~09A40~~			
~~12A00~~				~~12A40~~			
~~14A00~~				~~14A40~~			
~~16A00~~				~~16A40~~			

~~Space Cooling SSEER Test 41~~

~~Split system with 19 SEER~~

~~03A00~~				~~03A41~~			
~~09A00~~				~~09A41~~			
~~12A00~~				~~12A41~~			
~~14A00~~				~~14A41~~			
~~16A00~~				~~16A41~~			

~~**Space Cooling SSEER Test 42**~~

~~Package system, 11.7 SEER, sealed and tested ducts, and ACCA Manual D duct design~~

~~03A00~~				~~03A42~~			
~~09A00~~				~~09A42~~			
~~12A00~~				~~12A42~~			
~~14A00~~				~~14A42~~			
~~16A00~~				~~16A42~~			

~~**Optional Capability Test 51**~~

~~Controlled ventilation crawlspaces~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03B00~~				~~03B51~~			
~~09B00~~				~~09B51~~			
~~12B00~~				~~12B51~~			
~~14B00~~				~~14B51~~			
~~16B00~~				~~16B51~~			

~~Custom Budget Test~~

~~12B51~~				~~12B51C~~			

~~**Optional Capability Test 52**~~

~~Zonal Control~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A52~~			
~~09A00~~				~~09A52~~			
~~12A00~~				~~12A52~~			
~~14A00~~				~~14A52~~			
~~16A00~~				~~16A52~~			

~~Custom Budget Test~~

~~12A52~~				~~12A52C~~			

~~Optional Capability Test 53~~

~~Sunspaces~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A53~~			
~~09A00~~				~~09A53~~			
~~12A00~~				~~12A53~~			
~~14A00~~				~~14A53~~			
~~16A00~~				~~16A53~~			
~~Custom Budget Test~~							
~~12A53~~				~~12A53C~~			

~~Optional Capability Test 54~~

~~Side Fin Shading~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A54~~			
~~09A00~~				~~09A54~~			
~~12A00~~				~~12A54~~			
~~14A00~~				~~14A54~~			
~~16A00~~				~~16A54~~			
~~Custom Budget Test~~							
~~12A54~~				~~12A54C~~			

~~Optional Capability Test 55~~

~~Exterior Mass Walls~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~				~~03A55~~			
~~09A00~~				~~09A55~~			
~~12A00~~				~~12A55~~			
~~14A00~~				~~14A55~~			
~~16A00~~				~~16A55~~			

~~Custom Budget Test~~

~~12A55~~	________	________	________	~~12A55C~~	________	________	________

~~Optional Capability Test 56~~

~~Combined Hydronic Space and Water Heating~~

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Heating~~	~~Total~~
~~03A00~~	________	________	________	~~03A56K~~	________	________	________
~~09A00~~	________	________	________	~~09A56K~~	________	________	________
~~12A00~~	________	________	________	~~12A56K~~	________	________	________
~~14A00~~	________	________	________	~~14A56K~~	________	________	________
~~16A00~~	________	________	________	~~16A56K~~	________	________	________

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~	________	________	________	~~03A56L~~	________	________	________
~~09A00~~	________	________	________	~~09A56L~~	________	________	________
~~12A00~~	________	________	________	~~12A56L~~	________	________	________
~~14A00~~	________	________	________	~~14A56L~~	________	________	________
~~16A00~~	________	________	________	~~16A56L~~	________	________	________

	~~Basecase Building~~				~~Prototype Variation~~		
~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~	~~Label~~	~~Heating~~	~~Cooling~~	~~Total~~
~~03A00~~	________	________	________	~~03A56M~~	________	________	________
~~09A00~~	________	________	________	~~09A56M~~	________	________	________
~~12A00~~	________	________	________	~~12A56M~~	________	________	________
~~14A00~~	________	________	________	~~14A56M~~	________	________	________
~~16A00~~	________	________	________	~~16A56M~~	________	________	________

~~Custom Budget Test~~

~~12A56~~	________	________	________	~~12A56C~~	________	________	________

~~Optional Capability Test 57~~

~~Form 3 Generator~~

~~Label~~	~~U-value~~	~~R-value~~

~~W.19.EQ2~~	______	______
~~FC.30.2x10.16~~	______	______
~~FX.30.2x10.16~~	______	______
~~R.22.2x6.24~~	______	______
~~RP.22.2x6.48~~	______	______
~~R.38.2x4.24~~	______	______

ACM RB-2005

Appendix RB~~I~~ – Interior Mass Capacity

RB.1 Scope and Purpose

Interior Mass Capacity (IMC) is a measure of the total thermal mass in a low-rise residential building. IMC is used to determine if a building qualifies as a high mass building. Credit for thermal mass in the *Proposed Design* may only be considered when the *Proposed Design* qualifies as a high mass building. A high mass building is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15% of the conditioned non-slab floor exposed two inch thick concrete.

RB.2 Calculating Interior Mass Capacity (IMC)

The IMC for the building is calculated using Equation RB1. The IMC for the building is the sum of the area of each mass material multiplied times its Unit Interior Mass Capacity (UIMC). Table RB-1, Table RB-2, and Table RB-3 give UIMC values for a number of common thermal mass materials. This method allows for multiple mass types common in low-rise residential construction.

Equation RB-1

$$IMC = \sum_{I=1}^{n} A_I \times UIMC_I$$

where

IMC = Interior thermal mass of the building

A_i = Surface area of the i^{th} material

$UIMC_i$ = Unit Interior Mass Capacity (UIMC) of the i^{th} material selected from Table RB-1, Table RB-2, and Table RB-3

N = Number of thermal mass materials in the *Proposed Design*

RB.3 IMC Threshold for a High Mass Building

In order to qualify as a high mass building, the *Proposed Design* must have an IMC greater than or equal to that determined from Equation RD2. the IMC threshold is based on 30% of the conditioned slab area (CSA) being exposed (UIMC=4.6); 70% of the CSA being covered (UIMC=1.8); and 15% of the conditioned non-slab floor area as exposed two inch thick concrete (UIMC=2.5).

Equation RB-2

$$\begin{aligned} IMC_{Threshold} &= 0.3 \times 4.6 \times CSA + 0.7 \times 1.8 \times CSA + 0.15 \times 2.5 \times (CFA - CSA) \\ &= 2.640 \times CSA + 0.375 \times (CFA - CSA) \end{aligned}$$

where:

CSA = Conditioned Slab floor Area

CFA = Total Conditioned Floor Area

Table RB-1 – Interior Mass UIMC Values: Interior Mass[11]- Surfaces Exposed on One Side[13]

Material	Surface Condition	Mass Thickness (inches)	Unit Interior Mass Capacity
Concrete Slab-on-Grade and Raised Concrete Floors	Exposed[1]	2.00	3.6
		3.50	4.6
		6.00	5.1
	Covered[2]	2.00	1.6
		3.50	1.8
		6.00	1.9
Lightweight Concrete[9]	Exposed	0.75	1.0
		1.00	1.4
		1.50	2.0
		2.00	2.5
	Covered	0.75	0.9
		1.00	1.0
		1.50	1.2
		2.00	1.4
Solid Wood[9]	Exposed	1.50	1.2
		3.00	1.6
Tile[3,9]	Exposed	0.50	0.8
		1.00	1.7
		1.50	2.4
		2.00	3.0
Masonry[4,9]	Exposed	1.00	2.0
		2.00	2.7
		4.00	4.2
Adobe[9]	Exposed	4.00	3.8
		6.00	3.9
		8.00	3.9
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.1
	1.00" Gypsum	na	0.5
	0.88" Stucco	na	1.1
Masonry Infill[7]	0.50" Gypsum	3.50	1.3

Table RB-2 – Interior Mass UIMC Values: Interior Mass[11] - Surfaces Exposed on Two Sides[5, 13]

Material	Surface Condition	Mass Thickness (inches)	Unit Interior Mass Capacity
Partial Grout Masonry[4]	Exposed[1]	4.00	6.9
		6.00	7.4
		8.00	7.4
Solid Grout Masonry[4,6]	Exposed	4.00	8.3
		6.00	9.2
		8.00	9.6
Adobe	Exposed	4.00	7.6
		12.00	7.8
		16.00	7.6
Solid Wood/ Logs	Exposed	3.00	3.3
		4.00	3.3
		6.00	3.3
		8.00	3.3
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.2
	1.00" Gypsum	na	0.9
	0.88" Stucco	na	2.1
Masonry Infill[7]	0.50" Gypsum	3.50	2.6

Table RB-3 – Exterior Wall Mass UIMC Values[13]

Material	Surface Condition	Mass Thickness (inches)	Wall U-value	Unit Interior Mass Capacity
Solid Wood/	Exposed[1]	3.00	0.22	0.7
Logs		4.00	0.17	0.9
		6.00	0 .12	1.1
		8.00	0.093	1.2
		10.00	0.075	1.3
		12.00	0.063	1 .3
Wood Cavity Wall[12]	Exposed	3.00[12]	0.11	1.1
			0.065	1.3
			0.045	1.4
Adobe	Exposed	8.00	0.35	2.1
		16.00	0.21	2.8
		24.00	0.15	3.1
Masonry Veneer[4]	Framed Wall	4.00	0.10	na
			0.08	na
			0.06	na
Adobe Veneer	Framed Wall	4.00	0.10	na
			0.08	na
			0.06	na
Partial Grout Masonry[4]	Exposed[1]	4.00	0.68	0.9
			0.58	1.0
		6.00	0.54	1.3
			0.44	1.5
		8.00	0.49	1.5
			0.38	1.7
	Furred[10]	4.00	0.40	0.5
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		6.00	0.40	0.9
			0.30	0.6
			0.20	0.5
			0.10	0.5
			0.08	0.5
		8.00	0.30	0.8
			0.20	0.5
			0.10	0.5
			0.08	0.5

Table RB-3: Exterior Wall Mass UIMC Values (continued)[13]

Material	Surface Condition	Mass Thickness (inches)	Wall U-value	Unit Interior Mass Capacity
Solid Grout Masonry[4,6]	Exposed	4.00	0.79	1.0
		6.00	0.68	1.5
		8.00	0.62	1.8
	Furred[10]	4.00	0.40	0.5
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		6.00	0.40	0.7
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		8.00	0.40	0.8
			0.30	0.6
			0.20	0.5
			0.10	0.5
			0.08	0.5

RB.4 Table Notes

1. "Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.
2. "Covered" includes carpet, cabinets, closets or walls.
3. The indicated thickness includes both the tile and the mortar bed, when applicable.
4. Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.
5. The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.
6. "Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.
7. The indicated thickness for masonry infill is for the masonry material itself.
8. Use the Exterior Mass value for calculating Exterior Wall Mass.
9. Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.
10. "Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.
11. When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.
12. This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.
13. Values based on properties of materials listed in 1993 ASHRAE Handbook of Fundamentals.

~~The *Interior Mass Capacity (IMC)* of a material is calculated by multiplying its *Area* times its *Unit Interior Mass Capacity (UIMC)* using Equation I-1. Tables 3-2a, 3-2b and 3-3 list the UIMCs for a number of thermal mass materials. This method allows for multiple mass types in both raised-floor and slab-on-grade construction.~~

~~The *Interior Mass Capacity* for the *Standard Design* shall be determined as 20 percent of the *Proposed Design's* conditioned slab floor as 3.5 inch thick exposed slab (UIMC=4.6), 80% of the conditioned slab as 3.5 inch thick rug-covered slab (UIMC=1.8), and 5% of the *Proposed Design's* conditioned nonslab floor area as exposed 2 inch thick concrete (UIMC=2.5). If the user does not specify a high mass design, the *Interior Mass Capacity* of the *Proposed Design* shall be the same as for the *Standard Design*. If the user specifies a high mass design with an *Interior Mass Capacity* greater than the high mass threshold, the user is allowed to model the mass specified in the *Proposed Design*. The high mass threshold *Interior Mass* Capacity is determined as 30% of the conditioned floor area as exposed slab (UIMC=4.6), 70% of the conditioned slab floor area as rug-covered slab (UIMC=1.8), and 15% of the conditioned nonslab floor area as 2 inch thick concrete (UIMC=2.5).~~

~~*EQUATION NO. I-1*~~

~~*CALCULATION OF INTERIOR MASS CAPACITY*~~

~~$IMC = [(A_1 \times UIMC_1) + (A_2 \times UIMC_2) \ldots + (A_n \times UIMC_n)]$~~

~~*Where,*~~

~~A_n = *Area of mass material n, and*~~

~~$UIMC_n$ = *Unit Interior Mass Capacity of mass material n*~~

~~*Based on the UIMCs given above:*~~

~~$IMC_{threshold} = 2.64 \times CSA + 0.375 \times (CFA - CSA)$~~

~~*Where:*~~

~~*CSA = Conditioned Slab floor Area*~~

~~*CFA = total Conditioned Floor Area*~~

~~Table 3-2a: Interior Mass UIMC Values:~~

~~Interior Mass~~~~[11] –~~ **~~Surfaces Exposed on One Side~~**~~[13]~~

~~Material~~	**~~Surface Condition~~**	**~~Mass Thickness (inches)~~**	**~~Unit Interior Mass Capacity~~**
~~Concrete~~	~~Exposed~~[1]	~~2.00~~	~~3.6~~
~~Slab-on-Grade and~~		~~3.50~~	~~4.6~~
~~Raised Concrete Floors~~		~~6.00~~	~~5.1~~
	~~Covered~~[2]	~~2.00~~	~~1.6~~
		~~3.50~~	~~1.8~~
		~~6.00~~	~~1.9~~
~~Lightweight~~	~~Exposed~~	~~0.75~~	~~1.0~~
~~Concrete~~[9]		~~1.00~~	~~1.4~~
		~~1.50~~	~~2.0~~
		~~2.00~~	~~2.5~~
	~~Covered~~	~~0.75~~	~~0.9~~
		~~1.00~~	~~1.0~~
		~~1.50~~	~~1.2~~
		~~2.00~~	~~1.4~~
~~Solid Wood~~[9]	~~Exposed~~	~~1.50~~	~~1.2~~
		~~3.00~~	~~1.6~~
~~Tile~~[3,9]	~~Exposed~~	~~0.50~~	~~0.8~~
		~~1.00~~	~~1.7~~
		~~1.50~~	~~2.4~~
		~~2.00~~	~~3.0~~

~~Masonry[4,9]~~	~~Exposed~~	~~1.00~~	~~2.0~~
		~~2.00~~	~~2.7~~
		~~4.00~~	~~4.2~~
~~Adobe[9]~~	~~Exposed~~	~~4.00~~	~~3.8~~
		~~6.00~~	~~3.9~~
		~~8.00~~	~~3.9~~
~~Framed Wall~~	~~0.50" Gypsum~~	~~na~~	~~0.0~~
	~~0.63" Gypsum~~	~~na~~	~~0.1~~
	~~1.00" Gypsum~~	~~na~~	~~0.5~~
	~~0.88" Stucco~~	~~na~~	~~1.1~~
~~Masonry Infill[7]~~	~~0.50" Gypsum~~	~~3.50~~	~~1.3~~

~~Table 3-2 continued on next page.~~

~~Table 3-2b: Interior Mass UIMC Values:~~

~~Interior Mass[11] - Surfaces Exposed on Two Sides[5, 13]~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Unit Interior Mass Capacity~~
~~Partial Grout Masonry[4]~~	~~Exposed[1]~~	~~4.00~~	~~6.9~~
		~~6.00~~	~~7.4~~
		~~8.00~~	~~7.4~~
~~Solid Grout Masonry[4,6]~~	~~Exposed~~	~~4.00~~	~~8.3~~
		~~6.00~~	~~9.2~~
		~~8.00~~	~~9.6~~
~~Adobe~~	~~Exposed~~	~~4.00~~	~~7.6~~
		~~12.00~~	~~7.8~~
		~~16.00~~	~~7.6~~

~~Solid Wood/~~	~~Exposed~~	~~3.00~~	~~3.3~~
~~Logs~~		~~4.00~~	~~3.3~~
		~~6.00~~	~~3.3~~
		~~8.00~~	~~3.3~~
~~Framed Wall~~	~~0.50" Gypsum~~	~~na~~	~~0.0~~
	~~0.63" Gypsum~~	~~na~~	~~0.2~~
	~~1.00" Gypsum~~	~~na~~	~~0.9~~
	~~0.88" Stucco~~	~~na~~	~~2.1~~
~~Masonry Infill~~[7]	~~0.50" Gypsum~~	~~3.50~~	~~2.6~~

~~Notes follow Table 3-3.~~

~~Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors~~~~[13]~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Wall U-value~~	~~Unit Interior Mass Capacity~~	~~Exterior[8] Mass Factor~~
~~Partial Grout~~	~~Exposed~~~~[1]~~	~~4.00~~	~~0.68~~	~~0.9~~	~~1.1~~
~~Masonry~~~~[4]~~			~~0.58~~	~~1.0~~	~~1.0~~
		~~6.00~~	~~0.54~~	~~1.3~~	~~1.3~~
			~~0.44~~	~~1.5~~	~~1.1~~
		~~8.00~~	~~0.49~~	~~1.5~~	~~1.3~~
			~~0.38~~	~~1.7~~	~~1.2~~
	~~Furred~~~~[10]~~	~~4.00~~	~~0.40~~	~~0.5~~	~~0.9~~
			~~0.30~~	~~0.5~~	~~0.7~~
			~~0.20~~	~~0.5~~	~~0.5~~
			~~0.10~~	~~0.5~~	~~0.3~~
			~~0.08~~	~~0.5~~	~~0.2~~
		~~6.00~~	~~0.40~~	~~0.9~~	~~1.2~~
			~~0.30~~	~~0.6~~	~~1.0~~
			~~0.20~~	~~0.5~~	~~0.7~~
			~~0.10~~	~~0.5~~	~~0.4~~
			~~0.08~~	~~0.5~~	~~0.3~~
		~~8.00~~	~~0.30~~	~~0.8~~	~~1.0~~
			~~0.20~~	~~0.5~~	~~0.7~~
			~~0.10~~	~~0.5~~	~~0.4~~
			~~0.08~~	~~0.5~~	~~0.3~~
~~Solid Grout~~	~~Exposed~~	~~4.00~~	~~0.79~~	~~1.0~~	~~1.4~~
~~Masonry~~~~[4,6]~~		~~6.00~~	~~0.68~~	~~1.5~~	~~1.9~~
		~~8.00~~	~~0.62~~	~~1.8~~	~~2.1~~
	~~Furred~~~~[10]~~	~~4.00~~	~~0.40~~	~~0.5~~	~~1.0~~

	~~0.30~~	~~0.5~~	~~0.8~~
	~~0.20~~	~~0.5~~	~~0.6~~
	~~0.10~~	~~0.5~~	~~0.3~~
	~~0.08~~	~~0.5~~	~~0.3~~
~~6.00~~	~~0.40~~	~~0.7~~	~~1.4~~
	~~0.30~~	~~0.5~~	~~1.1~~
	~~0.20~~	~~0.5~~	~~0.7~~
	~~0.10~~	~~0.5~~	~~0.4~~
	~~0.08~~	~~0.5~~	~~0.3~~
~~8.00~~	~~0.40~~	~~0.8~~	~~1.5~~
	~~0.30~~	~~0.6~~	~~1.2~~
	~~0.20~~	~~0.5~~	~~0.8~~
	~~0.10~~	~~0.5~~	~~0.4~~
	~~0.08~~	~~0.5~~	~~0.3~~

~~Table 3-3 continued on next page~~

~~Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors~~[13]

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Wall U-value~~	~~Unit Interior Mass Capacity~~	~~Exterior[9] Mass Factor~~
~~Solid Wood/~~	~~Exposed~~[1]	~~3.00~~	~~0.22~~	~~0.7~~	~~0.5~~
~~Logs~~		~~4.00~~	~~0.17~~	~~0.9~~	~~0.6~~
		~~6.00~~	~~0 .12~~	~~1.1~~	~~0.6~~
		~~8.00~~	~~0.093~~	~~1.2~~	~~0.4~~
		~~10.00~~	~~0.075~~	~~1.3~~	~~0.3~~
		~~12.00~~	~~0.063~~	~~1 .3~~	~~0.3~~
~~Wood Cavity~~	~~Exposed~~	~~3.00~~[12]	~~0.11~~	~~1.1~~	~~0.5~~
~~Wall~~[12]			~~0.065~~	~~1.3~~	~~0.3~~
			~~0.045~~	~~1.4~~	~~0.2~~
~~Adobe~~	~~Exposed~~	~~8.00~~	~~0.35~~	~~2.1~~	~~1.5~~
		~~16.00~~	~~0.21~~	~~2.8~~	~~0.8~~
		~~24.00~~	~~0.15~~	~~3.1~~	~~0.5~~
~~Masonry~~	~~Framed Wall~~	~~4.00~~	~~0.10~~	~~na~~	~~0.3~~
~~Veneer~~[4]			~~0.08~~	~~na~~	~~0.3~~
			~~0.06~~	~~na~~	~~0.2~~
~~Adobe~~	~~Framed Wall~~	~~4.00~~	~~0.10~~	~~na~~	~~0.4~~
~~Veneer~~			~~0.08~~	~~na~~	~~0.3~~
			~~0.06~~	~~na~~	~~0.2~~

~~Notes For Tables 3-2 and 3-3:~~

1. ~~"Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.~~

2. ~~"Covered" includes carpet, cabinets, closets or walls.~~

3. ~~The indicated thickness includes both the tile and the mortar bed, when applicable.~~

4. ~~Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.~~

5. ~~The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.~~

6. ~~"Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.~~

7. ~~The indicated thickness for masonry infill is for the masonry material itself.~~

8. ~~Use the Exterior Mass value for calculating Exterior Wall Mass.~~

9. ~~Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.~~

10. ~~"Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.~~

11. ~~When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.~~

12. ~~This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.~~

13. ~~Values based on properties of materials listed in 1993 *ASHRAE Handbook of Fundamentals*.~~

~~APPENDIX B~~

~~The Contents of Appendix B Have Been Deleted.~~

~~Appendix B is~~

~~Reserved for Future Use for Sample CALRES Test Run Files and Input Descriptions for Tests 00 to 15.~~

~~These sample files will be added for information purposes only, and will not be adopted as regulations.~~

ACM RC-2005

Appendix RC~~F~~ – Procedures for Field Verification and Diagnostic Testing ~~Standard Procedure for Determining the Seasonal Energy Efficiencies~~ of Air Distribution Systems

RC~~F~~1 ~~Introduction~~Purpose and Scope

ACM RC-2005 contains procedures for measuring the air leakage in forced air distribution systems as well as procedures for verifying duct location, surface area and R-value.

ACM RC-2005 applies to air distribution systems in both new and existing low-rise residential buildings.

ACM RC-2005 provides required procedures for installers, HERS raters and others who need to perform field verification and diagnostic testing to verify the efficiency of air distribution systems. Algorithms for determining distribution system efficiency are contained in Chapter 4 of the residential ACM. Table RC-1 is a summary of the tests and criteria included in ACM RC-2005.

Table RC-1 – Summary of Diagnostic Measurements

Diagnostic	Description	Procedure
Supply Duct Location, Surface Area and R-factor	Verify that duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts.	RF4.3 Diagnostic Supply Duct Location, Surface Area and R-value
Duct Leakage	Verify that duct leakage is less than the criteria or in the case of existing ducts that all accessible leaks have been sealed	RC4.3 Diagnostic Duct Leakage

~~This appendix describes the measurement and calculation methods for determining air distribution system efficiency.~~

RC~~F~~2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RC~~F~~2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes as specified by the measurement equipment manufacturer.

~~RF4.1.2 Fan Flow Measurements~~

~~All measurements of distribution fan flows shall be made with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ±5% reading or ±5 cfm whichever is greater.~~

R<u>C</u>~~F~~2.<u>2</u>~~3~~ Duct Leakage Measurements

The measurement of air flows during duct leakage -testing shall have an accuracy of ±3% of measured flow using digital gauges.

<u>RC2.3 Calibration</u>

All instrumentation used for ~~fan flow and~~ duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

R<u>C</u>~~F~~3 Apparatus

<u>RC3.1 Duct Pressurization</u>

~~4.2.1 System Fan Flows~~

~~HVAC system fan flow shall be measured using one of the following methods.~~

~~*4.2.1.1 Plenum pressure matching measurement*~~

~~The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter [see section 4.3.7.2.2.]) meeting the specifications in 4.1.3, a static pressure transducer meeting the specifications in Section 4.1.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.~~

~~*4.2.1.2 Flow hood measurement*~~

~~A flow hood meeting the specifications in section 4.1.2. can be used to verify the fan flow at the return register(s) after the completion of a rough-in duct leakage measurement. All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).~~

~~*4.2.2 Duct Leakage*~~

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section <u>RC2</u>~~4.1.3~~.

<u>RC3.2 Duct Leakage to Outside (Existing Duct Systems)</u>

<u>The apparatus for measuring duct leakage to outside shall include a fan that is capable of maintaining the pressure within the conditioned spaces in the house 25 Pa relative to the outdoors. The fan most commonly used for this purpose is known as a "blower door"[gwp 2], and is typically installed within a temporary seal of an open doorway.</u>

<u>RC3.3 Smoke-Test Vof Accessible-Duct Sealing (Existing Duct Systems)</u>

<u>The apparatus for determining and verifying sealing of all accessible ducts shall also include means for introducing controllable amounts of non-toxic visual smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. Adequate smoke shall be used to assure that any accessible leaks will emit visibly identifiable smoke.</u>

R<u>C</u>~~F~~4 Procedure<u>s</u>

~~The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.~~

~~RF4.3.1 Building Information~~

~~The calculation procedure for determining air distribution efficiencies requires the following building information:~~

1. ~~Climate zone for the building,~~
2. ~~Conditioned floor area,~~
3. ~~Number of stories,~~
4. ~~Supply duct location and~~
5. ~~Floor type.~~

~~*4.3.1.1 Default Input*~~

~~Using default values rather than diagnostic procedures produce relatively low air distribution-system efficiencies.Default values shall be obtained from following sections:~~

1. ~~The location of the duct system in Section 4.3.4,~~
2. ~~The surface area and insulation level of the ducts in Sections 4.3.3, 4.3.4 and 4.3.6,~~
3. ~~The system fan flow in Section 4.3.7, and~~
4. ~~The leakage of the duct system in Section 4.3.8.~~

~~RF4.3.2 Diagnostic Input~~

~~Diagnostic inputs are used for the calculation of improved duct efficiency.~~ <u>This section describes procedures that may be used to verify diagnostic inputs for the calculation of improved duct efficiency.</u>

- ~~measure supply duct surface area as described in Section 4.3.3.2.~~
- ~~measure total duct system leakage as described in Section 4.3.8.~~
- ~~measure system fan flow or observe the presence of a thermostatic expansion valve for claiming ACCA manual D design credit as described in Section 4.3.7.~~
- ~~Observe the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section 4.3.6.~~
- ~~Observe the presence of radiant barriers.~~

~~RF4.3 Supply Duct Surface Area~~

~~The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one zone, the area of that duct in each zone shall be calculated separately. The duct surface area shall be determined using the following methods.~~

~~*RF 4.3.3.1 Default Duct Surface Area*~~

~~*4.3.3.1.1 Duct Surface Area for More than 12 feet of Duct Outside Conditioned Space*~~

~~The default duct surface area for supply and return shall be calculated as follows:~~

~~For supplies:~~

$$\cancel{A_{S,}\text{total} = 0.27 \times A_{floor}}$$ ~~Equation RF1~~

~~For returns:~~

~~Equation RF2~~

~~Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.~~

~~4.3.3.1.1 Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space~~

~~For HVAC systems with air handlers located outside the conditioned space but with less than 12 feet of duct located outside the conditioned space including air handler and plenum, the duct surface area outside the conditioned space shall be calculated as follows:~~

$$\cancel{A_{s,out} = 0.027\ A_{floor}}$$ ~~Equation RF3~~

~~Where $A_{s,out}$ is substituted for $A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$ depending on the location of the ducts.~~

~~RF4.3.3.2 Diagnostic Duct Surface Area~~

~~A well-designed duct system can reduce the length of the supply duct. Smaller duct surface area will result in reduced duct conduction losses. Duct surface area shall be calculated from measured duct lengths and nominal outside diameters (for round ducts) or outside perimeters (for rectangular ducts) of each duct run in the building. Improved conduction losses can be claimed for reduced supply duct surface area only (it does not apply to the return duct). Supply plenum surface area shall be included in the supply duct surface area. Diagnostic duct surface area requires measuring duct surface areas separately for each location outside conditioned space ($A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$~~

~~RF4.4 Duct Location~~

~~Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Default duct surface areas by locations of the supply duct shall be obtained from Table 4.1. The default duct surface area for crawlspace and basement applies only to buildings with all supply ducts installed in the crawlspace or basement. If the supply duct is installed in locations other than crawlspace or basement, the default supply duct location shall be "Other".~~

~~If ducts are installed in multiple locations, air distribution efficiency shall be calculated for each duct location. Total air distribution efficiency for the house shall be the weighted average based on the floor area served by each duct system.~~

	~~Supply Duct Surface Area~~		**~~Return Duct Surface Area~~**	
~~Supply or Return Duct Location~~	~~One story~~	~~Two or more story~~	~~One story~~	~~Two or more story~~
~~Attic~~	~~100% attic~~	~~65% attic 35% conditioned space~~	~~100% attic~~	~~100% attic~~
~~Crawlspace~~	~~100% crawlspace~~	~~65% crawlspace 35% conditioned space~~	~~100% attic~~	~~100% attic~~
~~Basement~~	~~100% Basement~~	~~65% basement 35% conditioned space~~	~~100% Basement~~	~~100% Basement~~
~~Other~~	~~100% attic~~	~~65% attic 35% conditioned space~~	~~100% attic~~	~~100% attic~~

~~4.3.5 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space~~

~~Duct ambient temperature for both heating and cooling at different duct locations shall be obtained from Table RF2. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be applied to cooling calculations. The procedures for the installation of radiant barriers shall be as described in ACM Section 4.23. Attic temperatures for houses with radiant barriers shall be obtained from Table RF2.~~

~~Table RF2 – Default Assumptions for Duct Ambient Temperature~~

	~~Duct Ambient Temperature for Heating, $T_{heat,amb}$~~			~~Duct Ambient Temperature for Cooling, $T_{cool,amb}$~~				
~~Climate zone~~	~~Attic~~	~~Crawlspace~~	~~Basement~~	~~Attic~~	~~Attic w/ radiant barrier (supply)~~	~~Attic w/ radiant barrier (return)~~	~~Crawlspace~~	~~Basement~~
~~1~~	~~52.0~~	~~52.2~~	~~48.9~~	~~60.0~~	~~65.4~~	~~61.2~~	~~54.0~~	~~49.1~~
~~2~~	~~48.0~~	~~48.7~~	~~56.5~~	~~87.0~~	~~84.3~~	~~84.2~~	~~78.0~~	~~64.5~~
~~3~~	~~55.0~~	~~54.9~~	~~58.3~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~62.8~~
~~4~~	~~53.0~~	~~53.1~~	~~56.6~~	~~79.0~~	~~78.7~~	~~77.4~~	~~70.9~~	~~61.4~~
~~5~~	~~49.0~~	~~49.6~~	~~52.3~~	~~74.0~~	~~75.2~~	~~73.1~~	~~66.4~~	~~56.8~~
~~6~~	~~57.0~~	~~56.7~~	~~59.9~~	~~81.0~~	~~80.1~~	~~79.1~~	~~72.7~~	~~64.1~~
~~7~~	~~62.0~~	~~61.1~~	~~60.4~~	~~74.0~~	~~75.2~~	~~73.1~~	~~66.4~~	~~61.6~~
~~8~~	~~58.0~~	~~57.6~~	~~60.1~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~63.9~~
~~9~~	~~53.0~~	~~53.1~~	~~59.6~~	~~87.0~~	~~84.3~~	~~84.2~~	~~78.0~~	~~66.4~~
~~10~~	~~53.0~~	~~53.1~~	~~61.1~~	~~91.0~~	~~87.1~~	~~87.6~~	~~81.6~~	~~68.9~~
~~11~~	~~48.0~~	~~48.7~~	~~59.5~~	~~95.0~~	~~89.9~~	~~91.0~~	~~85.1~~	~~69.5~~
~~12~~	~~50.0~~	~~50.4~~	~~59.3~~	~~91.0~~	~~87.1~~	~~87.6~~	~~81.6~~	~~67.8~~
~~13~~	~~48.0~~	~~48.7~~	~~58.4~~	~~92.0~~	~~87.8~~	~~88.4~~	~~82.4~~	~~67.6~~
~~14~~	~~39.0~~	~~40.7~~	~~55.4~~	~~99.0~~	~~92.7~~	~~94.4~~	~~88.7~~	~~68.6~~
~~15~~	~~50.0~~	~~50.4~~	~~63.4~~	~~102.~~	~~94.8~~	~~96.9~~	~~91.3~~	~~74.6~~
~~16~~	~~32.0~~	~~34.4~~	~~43.9~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~54.1~~

RC4.~~6~~ 1 Diagnostic Supply Duct Location, Surface Area and R-value~~Duct Wall Thermal Resistance~~

The performance calculations in ACM R4 allow credit for duct systems that are designed to be in advantageous locations, with reduced supply duct surface areas and/or higher than default R-values. Compliance credit may be taken for one or more of these duct system improvements in any combination. The procedure in this section is used to verify that the duct system is installed according to the design and meets the requirements for compliance credit.

RC4.1.1 Duct System Design Requirements

The design shall show the location of equipment and all supply and return registers. The size, R-value, and location of each duct segment shall be shown in the design drawing which shall be cross referenced to the Supply Duct System Details report in the CF1-R. For ducts buried in attic insulation, the portion in contact with the ceiling or deeply buried shall be shown and the design shall include provisions for ducts crossing each other, interacting with the structure, and changing vertical location to connect with elevated equipment or registers as required. Credit shall be allowed for buried ducts only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

RC4.1.2 Verifying the Duct System Installation

The location of all supply and return registers shall be verified from an inspection of the interior of the dwelling unit. The location of the equipment and the size, R-value and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the design shall not be allowed.

RC4.1.3 Verification for Ducts Buried in Attic Insulation

The procedure of RC4.2.2 shall be carried out prior covering the ducts with insulation. Ducts to be buried shall be insulated to R4.2 or greater. In addition ducts designed to be in contact with the ceiling shall be in continuous contact with the ceiling drywall or ceiling structure not more that 3.5 inches from the ceiling drywall. A sign must be hung near the attic access reading “Caution: Buried Ducts. Markers indicate location of buried ducts.” All ducts which will be completely buried shall have vertical markers which will be visible after insulation installation at not more than every 8 feet of duct length and at the beginning and end of each duct run.

After the ceiling insulation is installed, the R-value and type of insulation listed on the Duct System Details shall be verified. Ceiling insulation shall be level and uniform, mounding at ducts is not allowed.

RC4.2 System Fan Flow

For the purpose of establishing duct leakage criteria, the total fan flow shall be calculated using RC4.2.1, RC4.2.2 or RC4.2.3.

RC4.2.1 Default System Fan Flow

Default system fan flow may be used only for homes where the duct system is being tested before the air conditioning and heating system is installed and the equipment specification is not known. For heating only systems the default fan flow shall be 0.5 CFM/CFA. For systems with cooling, the default fan flow shall be 400 CFM per ton of rated cooling capacity calculated by the ACM using the procedure in ACM RF-2005 or the heating only value whichever is greater.

RC4.2.2 Nominal System Fan Flow

For heating only systems the fan flow shall be 21.7 x Heating Capacity in thousands of Btu/hr. For systems with cooling, the fan flow shall be 400 CFM per nominal ton of rated cooling capacity at ARI conditions or the heating only value whichever is greater.

RC4.2.2 Measured System Fan Flow

The fan flow shall be shall be as measured according to the procedure in ACM RF-2005.

~~*4.3.1 Default Duct Insulation R-value*~~

~~Default duct wall thermal resistance is R4.2. An air film resistance of 0.7 [h ft^2-°F/BTU] shall be added to the duct insulation R-value to account for external and internal film resistance.~~

~~*4.3.2 Diagnostic Duct Wall Thermal Resistance*~~

~~Duct wall thermal resistance shall be determined from the manufacturer’s specification observed during diagnostic inspection. If ducts with multiple R0values are installed, the lowest duct R-value shall be used. If a duct with a higher R value than 4.2 is installed, the R-value shall be clearly stated on the building plan and a visual inspection of the ducts must be performed to verify the insulation values. In case the space on top of the duct boot is limited and cannot be inspected, the insulation R-value within two feet of the boot to which the duct is connected may be excluded from the determination of the overall system R-value.~~

~~4.3.7 System Fan Flow~~

~~*4.3.7.1 Default Fan Flow*~~

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for climate zones 8 through 15 shall be calculated as follows:~~

~~Qe = 0.70 Afloor (4.4)~~ 4.7

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for **climate zones 1 through 7 and 16** and heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:~~

$$\cancel{Q_e = 0.50\ A_{floor}} \qquad \text{~~Equation RF4~~}$$

~~*4.3.7.2 Diagnostic Fan Flow*~~

~~To obtain duct efficiency credit for duct systems designed according to ACCA Manual D, a diagnostic fan flow measurement must be performed or the installation of a thermostatic expansion valve must be verified. The access panel on the cooling coil shall be removable for the verification of a thermostatic expansion valve. For ACCA Manual D designed duct system, engineering calculations and the building plan for duct sizing and layout shall also be prepared. The diagnostic fan flow measurement shall be measured using one of the following methods:~~

~~*4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood:*~~

~~To measure the system return fan flow, all registers shall be fully open, and the air filter shall be installed. Turn on the system fan and measure the fan flow at the return grille(s) with a calibrated flow hood to determine the total system return fan flow. The system fan flow (Q_e) shall be the sum of the measured return flows.~~

~~*4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching:*~~

~~The fan flow measurement shall be performed using the following procedures:~~

1. ~~With the system fan on (in heating mode with burners on for heating, or in cooling mode with compressor on), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (ΔP_{sp}). P_{sp} is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.~~
2. ~~Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.~~
3. ~~Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose. Assure that there is no significant leakage between the fan flowmeter and the system fan.~~
4. ~~If the fan flowmeter is connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.~~
5. ~~Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches P_{sp}.~~
6. ~~Record the flow through the flowmeter (Q_e, cfm) - this is the diagnostic fan flow.~~

~~In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach P_{sp}. In this case record the maximum flow (Q_{max}, cfm) and pressure (P_{max}) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Q_{max} and P_{max}) to operating condition (Q_e) at operating pressure (P_{sp}).~~

$$\cancel{Q_e = Q_{max}\left(\frac{P_{sp}}{P_{max}}\right)^{\frac{1}{2}} \qquad (4.6)}$$

~~4.3.8 Duct Leakage~~

~~*4.3.8.1 Duct Leakage Factor for Delivery Effectiveness Calculations*~~

~~Default duct leakage factors shall be obtained from Table RF3, using the "not Tested" values.~~

~~Duct leakage factors shown in Table RF3 shall be used in calculations of delivery effectiveness.~~

~~*Table RF3 – Duct Leakage Factors*~~

	~~**Duct Leakage Diagnostic Test Performed using Section 4.3.8.2 Procedures**~~	~~**$a_s = a_r =$**~~
~~Duct systems in homes built prior to 1999~~	~~Not tested~~	~~0.86~~
~~Duct systems in homes built after 1999~~	~~Not tested~~	~~0.89~~
~~Duct systems in homes of all ages, System with refrigerant based cooling, tested after house and HVAC system completion~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{ecool}~~	~~0.96~~
~~Duct systems in homes of all ages, System without refrigerant based cooling, tested after house and HVAC system completion~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{eheat}~~	~~0.96~~
~~Duct systems with refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{ecool} and final duct integrity verified~~	~~0.96~~
~~Duct systems without refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{eheat} and final duct integrity verified~~	~~0.96~~
~~Duct systems with refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.04 Q_{ecool} and final duct integrity verified~~	~~0.96~~
~~Duct systems without refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.04 Q_{eheat} and final duct integrity verified~~	~~0.96~~

RC4.~~8.2~~3 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to ~~quantify~~ verify that total leakage ~~for the calculation of air distribution efficiency~~ meets the criteria for any sealed duct system specified in the compliance documents. Diagnostic Duct Leakage from Fan Pressurization of Ducts (4.3.1) is the only procedure that may be used by a HERS rater to verify duct sealing in a new home. ~~To obtain the improved duct efficiency for sealing the duct system, a diagnostic leakage test as described in section 4.3.8.2.1 or 4.3.8.2.2 must be performed.~~ Table RC-2 shows the leakage criteria and test procedures that may be used to demonstrate compliance. In addition to the minimum tests shown, existing duct systems may be tested to show they comply with the criteria for new duct systems. ~~Houses built after 1/1/1999 shall not be allowed to claim duct leakage credit and diagnostic testing may not be done on any HVAC system that uses building cavities such as plenums or a platform return.~~

Table RC-2 Duct Leakage Tests

Case	User and Application	Leakage criteria, % of total fan flow	Procedure
Sealed and tested new duct systems	Installer Testing at Final HERS Rater Testing	6%	RC4.3.1
	Installer Testing at Rough- in, Air Handling Unit Installed	6% Installer Inspection at Final	RC4.3.2.1 RC4.3.2.3
	Installer Testing at Rough-in, Air Handling Unit Not Installed	4% Installer Inspection at Final	RC4.3.2.2 RC4.3.2.3
Sealed and tested altered existing duct system	Installer Testing HERS Rater Testing	15% Total Duct Leakage	RC4.3.1
	Installer Testing HERS Rater Testing	10% Leakage to Outside	RC4.3.3.
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Inspection and Smoke Test	RC4.3.4 RC4.3.6 and RC4.3.7
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	RC4.3.5 RC4.3.6 and RC4.3.7

RC4.3~~8~~.1~~2.1~~ Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing both the supply and return ~~the~~ ducts to a pressure difference of 25 Pascals. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots and registers are installed. The entire duct system shall be included in the total leakage test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used and if a platform or other building cavity used to house the air distribution system has been newly installed or altered, it contains a duct or is ducted with duct board or sheet metal.
3. Seal all the supply and return registers, except for one return register or the system fan access.

~~2~~4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.

~~3~~5. Install a static pressure probe at a supply.

~~4~~6. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.

~~5~~7. Record the flow through the flowmeter, ~~($Q_{total,25}$) -~~ this is the ~~total duct~~ leakage flow at 25 Pascals.

8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RF-2 the system passes.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table RC~~F~~3.

RC4.3.2~~8.2.2~~ Diagnostic Duct Leakage at Rough-in Construction Stage ~~Using An Aerosol Sealant Closure System~~

Installers may determine ~~D~~duct leakage in new construction ~~may be determined~~ by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing ~~wall when using an aerosol sealant closure system~~. When using this measurement technique, the installer shall complete additional ~~verification~~ inspection (as described in section RC4.~~3.8.2~~3.2.3) of duct integrity ~~shall be completed~~ after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The following procedure (either RC4.3.2.1 or RC4.3.2.2) shall be used: ~~The procedures in Sections 4.3.8.2.2.1 and 4.3.8.2.2.2 shall be used for measuring duct leakage before the interior finishing wall is installed.~~

RC4.3.~~8.2.~~2.1 For Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used ~~as part of~~to house the air distribution system, it ~~must~~ shall contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots.
5. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the duct system and outside or the building space with the entry door open to the outside.
6. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.~~Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa at rough-in stage.~~
7. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC2 the system passes.~~Divide the measured total leakage by the total fan flow calculated from Equation RF4 or RF5~~.

~~If the total leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table RF3.~~

RC4.3.~~8.2.~~2.2 For Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used ~~as part of~~to house the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.
3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.
4. Attach the fan flowmeter device at the unsealed duct box.
5. Insert a static pressure probe at one of the sealed supply duct boots.
6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.
7. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.

~~Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa.~~

8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC-2 the system passes.~~Divide the measured total leakage by the total~~

~~fan flow calculated from Equation RF4 or RF5. If the total leakage is less than 4% of the total fan flow, the total duct leakage factor shall be 0.96 as shown in Table RF3 Table 4.3.~~

RC4.3~~8.2.~~2.3 Installer Visual Inspection at Final Construction Stage~~Post Rough-in Duct Leakage Verification~~

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, the following procedure shall be used: ~~one of the following post rough-in verification tests shall be performed to ensure that there is no major leakage in the duct system.~~

1. Remove at least one supply and one return register, and verify that the spaces between the register boot and the interior finishing wall are properly sealed.
2. If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.
3. Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.

~~4.8.2.2.3.1 Visual Inspection~~

~~Remove at least one supply and one return register to verify that the spaces between the register boot and the interior finishing wall are properly sealed. In addition, if the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.~~

~~4.8.2.2.3.2 Pressure Pan Test~~

~~With register dampers fully open, the house is pressurized to 25 pascals by a blower door, (if two registers are within 5 feet of each other and are connected to the same duct run, one register shall be sealed off before the pressure pan test is performed). The pressure difference across each register shall not exceed 1.5 Pa.~~

~~4.8.2.2.3.3 House Pressure Test~~

~~The pressure difference between the building conditioned space and a vented attic shall be measured to determine whether the house pressure is changed appreciably by the operation of the air handler. To perform this test, the pressure difference~~ ~~(P_{house} - P_{out})~~ ~~between the building conditioned space and a vented attic (or outside if impossible to access the attic), shall be measured four times:~~

~~1. With the fan off~~ ~~(ΔP_{off1})~~

~~2. With the fan on~~ ~~(ΔP_{on})~~

~~3. With the fan on and the return grille 80% blocked~~ ~~(ΔP_{RB})~~~~. Block 80% on all return grilles if the house has two or more returns.~~

~~4. With the fan off~~ ~~(ΔP_{off2})~~

~~For each of these measurements, the five-second average pressure shall be measured 10 times and these 10 measurements shall be averaged.~~

~~For the house to pass this test, the following conditions must be true:~~

~~1.~~ ~~$\Delta P_{on} - (\Delta P_{off2} + \Delta P_{off1})/2$~~ ~~must be between +0.8 Pa and -0.8 Pa and~~

~~2.~~ ~~$\Delta P_{RB} - \Delta P_{on}$~~ ~~must be less than 0.8 Pa.~~

~~In addition, the absolute value of~~ ~~$(\Delta P_{off2} - \Delta P_{off1})$~~ ~~must be less than 0.25 Pa, or else the test must be repeated. If the repeated test does not meet the above specified values, visual inspection or the pressure pan test or the fan pressurization test must be used. If these tests fail, the duct system needs to be properly sealed and re-verified by a fan pressurization test.~~

RC4.3.3 Duct Leakage to Outside from Fan Pressurization of Ducts

The objective of this test for altered existing duct systems only is to provide an alternate measurement of duct leakage to outdoors. The total duct leakage to outdoors shall be determined by pressurizing the ducts and the conditioned spaces of the house to 25 Pa. The following procedure shall be used for the fan pressurization test of leakage to outside:

1. Seal all the supply and return registers except one return register or the fan access door.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at the supply plenum.
4. Attach a blower door to an external doorway.
5. If any ducts are located in an unconditioned basement, all doors or accesses between the conditioned space and the basement shall be closed, and at least one operable door or window (if it exists) between the basement and outside shall be opened during the test.
6. If the ducts are located in a conditioned basement, any door between the basement and the remaining conditioned space shall be opened, and any basement doors or windows to outside must be closed during the test.
7. Adjust the blower door fan to provide 25 Pa [0.1 inches of water] pressure difference between the conditioned space and outside.
8. Adjust the fan/flowmeter to maintain zero pressure (±0.5Pa [±0.002 inches water]) between the ducts and the conditioned space, and adjust the blower door fan to maintain 25 Pa (±0.5Pa) [0.1 inch water (±0.002 inches water)] between the conditioned space and outside. This step may require several iterations[gwp 7].
9. Record the flow through the flowmeter (Q25 [Q0.1]); this is the duct leakage at 25 Pa [0.1 inch water].
10. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC-2 the system passes.

RC4.3.4 Leakage Improvement from Fan Pressurization of Ducts

For altered existing duct systems which do not pass the Total Leakage (RC4.3.1) or Leakage to Outside (RC4.3.3) tests, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table RC-2 The following procedure shall be used:.

1. Use the procedure in RC4.3.1 to measure the leakage before commencing duct sealing.
2. After sealing is complete use the same procedure to measure the leakage after duct sealing.
3. Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60% or greater of the original leakage, the system passes.
4. Complete the Smoke Test specified in RC4.3.6
5. Complete the Visual Inspection specified in RC4.3.7.

RC4.3.5 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass any of the Total Leakage (RC4.3.1), Leakage to Outside (RC4.3.3) or Leakage Improvement (RC4.3.4) tests, the objective of this test is to show that all accessible leaks are sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Complete each of the leakage tests
2. Complete the Smoke Test as specified in RC4.3.6
3. Complete the Visual Inspection as specified in RC4.3.7.
4. Install required label on the system stating that the system fails the leakage tests.

RC4.3.6 Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa relative to the duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if either of the following conditions are met:

i. No visible smoke exits the accessible portions of the duct system.; or

ii. Smoke only emanates from the portion of the HVAC equipment containing the furnace vestibule which is gasketed and sealed by the manufacturer rather than from the ducts.

RC4.3.7 Visual Inspection of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of this inspection in conjunction with the smoke test (RC4.3.6) is to confirm that all accessible leaks have been sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Visually inspect to verify that the following locations have been sealed:
   - Connections to plenums and other connections to the forced air unit
   - Refrigerant line and other penetrations into the forced air unit
   - Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
   - Register boots sealed to surrounding material
   - Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.
2. Visually inspect to verify that portions of the duct system that are excessively damaged have been replaced. Ducts that are considered to be excessively damaged are:
   - Flex ducts with the vapor barrier split or cracked with a total linear split or crack length greater than 12 inches
   - Crushed ducts where cross-sectional area is reduced by 30% or more
   - Metal ducts with rust or corrosion resulting in leaks greater than 2 inches in any dimension
   - Ducts that have been subject to animal infestation resulting in leaks greater than 2 inches in any dimension

~~4.4 Delivery Effectiveness (DE) Calculations~~

~~Seasonal delivery effectiveness shall be calculated using the seasonal design temperatures from Tables RF2.~~

~~4.4.1 Calculation of Duct Zone Temperatures~~

~~The temperatures of the duct zones outside the conditioned space are determined in Section 4.3.5 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures:~~

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out} + 0.001}$$ ~~Equation RF5~~

~~$$T_{amb,r} = \frac{A_{r,attic}\ T_{attic} + A_{r,crawl} \times T_{crawl} + A_{r,base} \times T_{base}}{A_{r,out}}$$ Equation RF6~~

~~The return ambient temperature, $T_{amb,r}$, shall be limited as follows:~~

~~For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$. For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.~~

~~4.4.2 Seasonal Delivery Effectiveness (DE)~~

~~The supply and return conduction fractions, B_s and B_r, shall be calculated as follows:~~

~~$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 Q_e \times R_s}\right)$$ Equation RF7~~

~~$$B_r = \exp\left(\frac{-A_{r,out}}{1.08 Q_e \times R_r}\right)$$ Equation RF8~~

~~The temperature difference across the heat exchanger in the following equation is used:~~

~~for heating:~~

~~$\Delta T_e = 55$ Equation RF9~~

~~for cooling:~~

~~$\Delta T_e = -20$ Equation RF10~~

~~The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r, shall be calculated using the indoor and the duct ambient temperatures.~~

~~$\Delta T_s = T_{in} - T_{amb,s}$ Equation RF11~~

~~$\Delta T_r = T_{in} - T_{amb,r}$ Equation RF12~~

~~The seasonal delivery effectiveness for heating or cooling systems shall be calculated using:~~

~~$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$ Equation RF13~~

~~4.5 Seasonal Distribution System Efficiency~~

~~Seasonal distribution system efficiency shall be calculated using delivery effectiveness, equipment, load, and recovery factors calculated for seasonal conditions.~~

~~4.5.1 Equipment Efficiency Factor (F_{equip})~~

~~Equipment efficiency factor accounts for interactions between the duct system and the operation of the heating or cooling equipment. If the duct size and layout are designed and installed according to ACCA manual D and if the fan flow measurement meets the design specifications, the efficiency factor for F_{equip} is 1. Otherwise F_{equip} shall be 0.925. For heating, F_{equip} is 1.~~

~~4.5.2 Thermal Regain (F_{regain})~~

~~The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The default thermal regain factors are provided in Table RF4.~~

~~RFThermal Regain Factors~~

~~Supply Duct Location~~	~~Thermal Regain Factor [F_{regain}]~~
~~Attic~~	~~0.10~~
~~Crawlspace~~	~~0.12~~
~~Basement~~	~~0.30~~
~~Other~~	~~0.10~~

~~*RF5 Definitions*~~

~~***aerosol sealant closure system**: A method of sealing leaks by blowing aerosolized sealant particles into the duct system and which must include minute-by-minute documentation of the sealing process.*~~

~~***floor area** :The floor area of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces enclosing the conditioned space.*~~

~~***delivery effectiveness** :The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.*~~

~~***distribution system efficiency** :The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.*~~

~~***equipment efficiency** :The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.*~~

~~***equipment factor** : F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.*~~

~~***fan flowmeter device**: A device used to measure air flow rates under a range of test pressure differences.*~~

~~***flowhood**: A device used to capture and measure the airflow at a register.*~~

~~***load factor** : F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.*~~

~~***pressure pan** : a device used to seal individual forced air system registers and to measure the static pressure from the register.*~~

~~***radiant barrier** : a surface of low emissivity (less than 0.05) placed inside an attic or roof space to reduce radiant heat transfer.*~~

~~***recovery factor** : F_{recov} is the fraction of energy lost from the distribution system that enters the conditioned space.*~~

~~***thermal regain:** The fraction of delivery system losses that are returned to the building.*~~

~~*RF6 Nomenclature*~~

~~a_r = duct leakage factor (1-return leakage) for return ducts~~

~~a_s = duct leakage factor (1-supply leakage)p for supply ducts~~

~~A_{floor} = conditioned floor area of building, ft^2~~

~~$A_{r,out}$ = surface area of return duct outside conditioned space, ft^2~~

~~$A_{r,attic}$ = return duct area in attic, ft^2~~

~~$A_{r,base}$ = return duct area in basement, ft^2~~

~~$A_{r,crawl}$ = return duct area in crawlspace, ft^2~~

~~$A_{r,gar}$ = return duct area inside garage, ft^2~~

~~$A_{s,out}$ = surface area of supply duct outside conditioned space, ft^2~~

~~$A_{s,attic}$ = supply duct area in attic, ft^2~~

~~$A_{s,base}$ = supply duct area in basement, ft^2~~

~~$A_{s,crawl}$ = supply duct area in crawlspace, ft^2~~

~~$A_{s,gar}$ = supply duct area inside garage, ft^2~~

~~$A_{s,in}$ = supply duct area inside conditioned space, ft^2~~

~~B_r = conduction fraction for return~~

~~B_s = conduction fraction for supply~~

~~DE = delivery effectiveness~~

~~DE_{design} = design delivery effectiveness~~

~~$DE_{seasonal}$ = seasonal delivery effectiveness~~

~~E_{equip} = rate of energy exchanged between equipment and delivery system, Btu/hour~~

~~$F_{cycloss}$ = cyclic loss factor~~

~~F_{equip} = load factor for equipment~~

~~F_{flow} = load factor for fan flow effect on equipment efficiency~~

~~F_{leak} = fraction of system fan flow that leaks out of supply or return ducts~~

~~F_{load} = load factor for delivery system~~

~~F_{recov} = thermal loss recovery factor~~

~~F_{regain} = thermal regain factor~~

~~K_r = return duct surface area coefficient~~

~~K_s = supply duct surface area coefficient~~

~~N_{story} = number of stories of the building~~

~~P_{sp} = pressure difference between supply plenum and conditioned space [Pa]~~

~~P_{test} = test pressure for duct leakage [Pa]~~

~~Q_e = Flow through air handler fan at operating conditions, cfm~~

~~$Q_{total,25}$ = total duct leakage at 25 Pascal, cfm~~

~~R_r = thermal resistance of return duct, h ft^2 F/Btu~~

~~R_s = thermal resistance of supply duct, h ft^2 F/Btu~~

~~$T_{amb,r}$ = ambient temperature for return, F~~

~~$T_{amb,s}$ = ambient temperature for supply, F~~

~~T_{attic} = attic air temperature, F~~

~~T_{base} - return duct temperature in basement, F~~

~~T_{crawl} - return duct temperature in crawlspace, F~~

~~T_{design} = outdoor air design temperature, F~~

~~T_{ground} = ground temperature, F~~

~~T_{gar} = temperature of garage air, F~~

~~T_{in} = temperature of indoor air, F~~

~~T_{rp} = return plenum air temperature, F~~

~~$T_{seasonal}$ = outdoor air seasonal temperature, F~~

~~T_{sp} = supply plenum air temperature, F~~

~~ΔT_e = temperature rise across heat exchanger, F~~

~~ΔT_r = temperature difference between indoors and the ambient for the return, F~~

~~ΔT_s = temperature difference between indoors and the ambient for the supply, F~~

~~$\eta_{dist,seasonal}$ = seasonal distribution system efficiency~~

~~*RF4.0 Air Distribution Diagnostic Measurement and Default Assumptions*~~

~~4.5.3 Recovery Factor (F_{recov})~~

~~The recovery factor, F_{recov}, is calculated based on the thermal regain factor, F_{regain}, and the duct losses without return leakage.~~

$$F_{recov} = 1 + F_{regain}\left(\frac{1 - a_s B_s + a_s B_s (1 - B_r)\frac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s)\frac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right)$$ ~~Equation RF14~~

~~4.5.4 Seasonal Distribution System Efficiency~~

~~The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness from Section 4.4.2, the equipment efficiency factor from Section 4.5.1 and the thermal recovery factor from Section 4.5.3. Note that $DE_{seasonal}$, F_{equip}, F_{recov} must be calculated separately for cooling and heating conditions. Distribution system efficiency shall be determined using the following equation:~~

$$\eta_{dist,seasonal} = 0.98\, DE_{seasonal} \times F_{recov}$$ ~~Equation RF15~~

~~where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass.~~

~~APPENDIX C~~

~~Pages C-4 through C-60 have been deleted but are reserved for future use for final versions of the sample CALRES input descriptions of the C prototype building and the Custom Budget tests.~~

~~These sample files will be added for information purposes only, and will not be adopted as regulations.~~

~~Pages C-1 to C-3 are available upon request by calling Debbie Friese at (916) 654-4067.~~

ACM RD-2005

Appendix RD~~K~~ – Procedures for Determining ~~Required~~ Refrigerant Charge ~~and Adequate Airflow~~ for Split System Space Cooling Systems without Thermostatic Expansion Valves

RD~~K~~1 Purpose and Scope~~Overview~~

~~Failure to maintain proper refrigerant charge or proper airflow across the coil reduces the seasonal energy efficiency for an air conditioner (whether a cooling only air conditioner or a heat pump). In addition, excessive refrigerant charge can cause premature compressor failure, while insufficient refrigerant charge allows compressors to overheat. Very low airflow can result in icing of the coil and compressor failure.~~

~~To help avoid these problems and to provide a compliance credit for correctly installed systems,~~ The purpose of this ~~this appendix describes~~ procedure~~s~~ is to determine and verify that ~~for determining if a~~ residential split system space cooling systems and heat pumps have ~~has~~ the required refrigerant charge ~~and adequate airflow across the evaporator coil~~. The ~~applicability of these~~ procedures ~~have the following limitations: The procedures detailed in this appendix~~ only apply to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs). ~~As an alternative to the procedures detailed in this appendix, systems may substitute a TXV installed and confirmed through field verification and diagnostic testing.~~ The procedures ~~detailed in this appendix~~ do not apply to ~~single~~ packaged systems. For dwelling units with multiple split systems or heat pumps, the procedure shall be applied to each system separately.

~~Note that t~~The procedures detailed in ~~this appendix~~ ACM RD-2005 are intended to be used after the HVAC installer has installed and charged the air conditioner or heat pump system in accordance with the ~~manufacturer's specifications. The installer shall install and charge the air conditioner and heat pump equipment in accordance with the~~ manufacturer's instructions and specifications for the specific model equipment installed. The installer shall certify to the builder, building official and HERS rater that ~~they have~~ he/she has followed ~~these~~ the manufacturer's instructions and specifications prior to proceeding with the procedures in this appendix.

A~~For dwelling units with multiple systems, this procedure must be applied to each system separately.~~

~~This appendix~~ ACM RD-2005 defines two procedures, the Standard Charge ~~and Airflow~~ Measurement ~~procedure~~ Procedure in Section RD2 and the Alternate Charge ~~and Airflow~~ Measurement P~~p~~rocedure in Section RD3. The Standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the Alternate procedure.

The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure. Note: Wherever thermocouples appear in this document, thermisters can be used instead with the same requirements applying to thermisters as to thermocouples.

The reference method algorithms adjust (improve) the efficiency of split system air conditioners and heat pumps when they are diagnostically tested to have the correct refrigerant charge or when field verification indicates that a TXV has been installed. Table RD-1 summarizes the algorithms that are affected by refrigerant charge testing or field verification of a TXV.

Table RD-1 – Summary of Diagnostic Measurements

Input to the Algorithms	Variables and Equation Reference	Description	Standard Design Value	Proposed Design Default Value	Proposed Design Procedure
Cooling System Refrigerant Charge	F_{TXV} (Eq. 4.42 and 4.43)	F_{TXV} takes on a value of 0.96 when the system has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{TXV} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a TXV, when required by Package D.	No refrigerant charge testing or TXV.	RD2 or RD3

Note that a prerequisite for diagnostically testing the refrigerant charge is to verify that there is adequate airflow over the evaporator coil. This diagnostic test is described in ACM RE-2005.

RD~~K~~2 Standard Charge ~~and Airflow~~ Measurement Procedure

This section specifies the Standard charge ~~and airflow~~ measurement procedure. Under this procedure, required refrigerant charge is calculated using the *Superheat Charging Method*. ~~and~~ The method also checks ~~adequate~~ airflow across the evaporator coil ~~is~~ to determine whether the charge test is valid ~~calculated~~ using the *Temperature Split Method* or the air flow measurement methods in ACM RE-2005.

The Standard procedure detailed in this section shall be completed when the outdoor temperature is 55°F or higher after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. If the outdoor temperature is between 55°F and 65°F the return dry bulb temperature shall be maintained above 70°F during the test. All HERS rater verifications are required to use this Standard procedure.

RD~~K~~2.1 Minimum Qualifications for this Procedure

Persons carrying out this procedure ~~need to~~shall be qualified to perform the following:

- Obtain accurate pressure/temperature readings from refrigeration manifold gauges.
- Obtain accurate temperature readings from thermometer and thermocouple set up.
- Check calibration of refrigerant gauges using a known reference pressure and thermometer/thermocouple set up using a known reference temperature.
- Determine best location for temperature measurements in ducting system and on refrigerant line set.
- Calculate the measured superheat and temperature split.
- Determine the correct level of superheat and temperature split required, based on the conditions present at the time of the test.
- Determine if measured values are reasonable.

RD~~K~~2.2 Instrumentation Specifications

Instrumentation for the procedures described in this section shall conform to the following specifications:

RD~~K~~2.2.1 Digital Thermometer

Digital thermometer ~~must~~ shall have thermocouple compatibility (type K and J) and Celsius or Fahrenheit readout with:

- Accuracy: ±(0.1% of reading + 1.3º F).
- Resolution: 0.2º F.

RD~~K~~2.2.2 Thermocouples

Measurements require five (5) heavy duty beaded low-mass wire thermocouples and one (1) cotton wick for measuring wet-bulb temperatures.

RD~~K~~2.2.3 Refrigerant Manifold Gauge Set

A standard multiport refrigerant manifold gauge with an accuracy of plus or minus 3% shall be used.

RD~~K~~2.3 Calibration

The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.

RD~~K~~2.3.1 Thermometer/Thermocouple Field Calibration Procedure

Thermometers/thermocouples shall be calibrated monthly to ensure that they are reading accurate temperatures. The following procedure shall be used to check thermometer/thermocouple calibration:

1. ~~Step 1~~ Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.
2. ~~Step 2~~ Insert two thermocouples into the center of the ice bath and attach them to the digital thermometer.
3. ~~Step 3~~ Let the temperatures stabilize. The temperatures shall be 32°F (+/- 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any thermocouples that are off by more than 3°F shall be replaced.
4. ~~Step 4~~ Switch the thermocouples and ensure that the temperatures read on T1 and T2 are still within +/- 1°F of 32°F.
5. ~~Step 5~~ Affix sticker with calibration check date onto thermocouple.
6. ~~Step 6~~ Repeat the process for all thermocouples.

RD~~K~~2.3.2 Refrigerant Gauge Field Check Procedure

Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration:

1. ~~Step 1~~ Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.
2. ~~Step 2~~ Attach a thermocouple to the refrigerant cylinder using duct tape so that there is good contact between the cylinder and the thermocouple.
3. ~~Step 3~~ Insulate the thermocouple connection to the cylinder (closed cell pipe insulation can be taped over the end of the thermocouple to provide the insulation).
4. ~~Step 4~~ Zero the low side compound gauge with all ports open to atmospheric pressure (no hoses attached).
5. ~~Step 5~~ Re-install the hose and attach the low side gauge to the refrigerant cylinder.
6. ~~Step 6~~ Read the temperature of the thermocouple.
7. ~~Step 7~~Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.
8. ~~Step 8~~If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration.
9. ~~Step 9~~Repeat the process in steps 4 through 8 for the high side gauge.
10. ~~Step 10~~Affix sticker with calibration check date onto refrigerant gauge.

RD~~K~~2.4 Charge ~~and Airflow~~ Measurements

The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge ~~and adequate airflow~~ as described in the following sections:

~~Step 1.~~1. If the condensor air entering temperature is less than 65°F, ~~E~~establish a return air dry bulb temperature sufficiently high that the return air dry bulb temperature will be not less than 70°F prior to the measurements at the end of the 15 minute period in step 2.

2. ~~Step 2~~ Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature measurements.
3. ~~Step 3~~ Connect the refrigerant gauge manifold to the suction line service valve.
4. ~~Step 4~~ Attach a thermocouple to the suction line near the suction line service valve. Be sure the sensor is in direct contact with the line and is well insulated from air temperature.
5. ~~Step 5~~Attach a thermocouple to measure the condenser (entering) air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.
6. ~~Step 6~~ Be sure that all cabinet panels that affect airflow are in place before making measurements. The thermocouple sensors shall remain attached to the system until the final charge is determined.
7. ~~Step 7~~Place wet-bulb thermocouple in water to ensure it is saturated when needed. **Do not get the dry-bulb thermocouples wet.**
8. ~~Step 8~~Insert the dry-bulb thermocouple in the supply plenum at the center of the airflow.
9. ~~Step 9~~At 12 minutes, insert a dry-bulb thermocouple and a wet-bulb thermocouple into the return plenum at the center of the airflow.
10. ~~Step 10~~At 15 minutes when the return plenum temperatures have stabilized, using the thermocouples already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return,\ db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return,\ wb}$).
11. ~~Step 11~~ Using the dry-bulb thermocouple already in place, measure and record the supply (evaporator leaving) air dry-bulb temperature ($T_{supply,\ db}$).
12. ~~Step 12~~ Using the refrigerant gauge already attached, measure and record the evaporator saturation temperature ($T_{evaporator,\ sat}$) from the low side gauge.
13. ~~Step 13~~ Using the dry-bulb thermocouple already in place, measure and record the suction line temperature ($T_{suction,\ db}$).
14. ~~Step 14~~ Using the dry-bulb thermocouple already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser,\ db}$).

The above measurements shall be used to adjust refrigerant charge and airflow as described in following sections.

R<u>D</u>~~K~~2.5 Refrigerant Charge Calculations

The Superheat Charging Method is used only for non-TXV systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices. The following steps describe the calculations to determine if the system meets the required refrigerant charge using the measurements described in section <u>RD</u>2.4. If a system fails, then remedial actions must be taken. If the refrigerant charge is changed and the airflow has been previously tested and shown to pass, then the airflow shall be re-tested. Be sure to complete Steps 1 and 2 of Section <u>RD</u>2.4 before re-testing the airflow. Both the airflow and charge must be re-tested until they both sequentially pass.

1. ~~Step 1~~Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.

$$\text{Actual Superheat} = T_{suction,\ db} - T_{evaporator,\ sat}.$$

2. ~~Step 2~~ Determine the Target Superheat using Table R<u>D</u>2~~K-1~~ using the return air wet-bulb temperature ($T_{return,\ wb}$) and condenser air dry-bulb temperature ($T_{condenser,\ db}$).

3. ~~Step 3~~ If a dash mark is read from Table RD-2~~Table K-1~~, the target superheat is less than 5°F, then the system **does not pass** the required refrigerant charge criteria, usually because outdoor conditions are too hot and dry. One of the following adjustments is needed until a target superheat value can be obtained from Table RD-2~~Table K-1~~ by either 1) turning on the space heating system and/or opening the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. After adjustments, repeat the measurement procedure as often as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before completing the measurement procedure again.
4. ~~Step 4~~ Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat)
5. ~~Step 5~~If the difference is between minus 5 and plus 5°F, then the system **passes** the required refrigerant charge criteria.
6. ~~Step 6~~ If the difference is greater than plus 5°F, then the system **does not pass** the required refrigerant charge criteria and the installer shall add refrigerant. After the refrigerant has been added, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement procedure as many times as necessary to pass the test.
7. ~~Step 7~~If the difference is between –5 and -100°F, then the system **does not pass** the required refrigerant charge criteria, the installer shall remove refrigerant. After the refrigerant has been removed, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement as many times as necessary to pass the test.

RD~~K~~2.6~~5~~ ~~Adequate~~ Airflow ~~Calculations~~Verification

In order to have a valid charge test, the air flow shall be verified by either passing the temperature split test or by one of the three measurements in ACM RE-2005 with a measured airflow in excess of 0.033 cfm/Btu capacity rated at DOE A test conditions (400 cfm/12000 Btu) (dry coil).

The temperature split test method is designed to provide an efficient check to see if airflow is above the required minimum for a valid refrigerant charge test. The following steps describe the calculations using the measurement procedure described in section RD2.4. If a system fails, then remedial actions must be taken. If the airflow is changed and the refrigerant charge has previously been tested and shown to pass, then the refrigerant charge shall be re-tested. Be sure to complete Steps 1 and 2 of Section RD2.4 before re-testing the refrigerant charge. Both the airflow and charge must be re-tested until they both sequentially pass.

1. ~~Step 1~~Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split = $T_{return,\ db} - T_{supply,\ db}$
2. ~~Step 2~~Determine the Target Temperature Split from Table RD-3~~Table RK-2~~ using the return air wet-bulb temperature ($T_{return,\ wb}$) and return air dry-bulb temperature ($T_{return,\ db}$).
3. ~~Step 3~~If a dash mark is read from Table RD-3~~Table RK-2~~, then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section RD3.4 below.
4. ~~Step 4~~Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split). If the difference is within plus 3°F and minus 3°F, then the system **passes** the adequate airflow criteria.
5. ~~Step 5~~If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure as often as necessary to establish adequate airflow range. Allow system to stabilize for 15 minutes before repeating measurement procedure.
6. ~~Step 6~~If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow.

7. ~~Step 7~~If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).

RD~~K~~3 Alternate Charge ~~and Airflow~~ Measurement Procedure

This section specifies the Alternate charge ~~and airflow~~ measurement procedure. Under this procedure, the required refrigerant charge is calculated using the *Weigh-In Charging Method*.

~~and adequate airflow across the evaporator coil is calculated using the Measured Airflow Method.~~

HVAC installers who must complete system installation verification when the outdoor temperature is below 55°F shall use this Alternate procedure in conjunction with installing and charging the system in accordance with the manufacturer's specifications. HERS Raters shall not use this procedure to verify compliance.

Split system air conditioners come from the factory already charged with the standard charge indicated on the name plate. The manufacturer supplies the charge proper for the application based on their standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line length different from the manufacturer's standard.

RD~~K~~3.1 Minimum Qualifications for this Procedure

HVAC installation technicians ~~need to~~shall be qualified to perform the following:

1. ~~Step 1~~Transfer and recovery of refrigerant (including a valid Environmental Protection Agency (EPA) certification for transition and recovery of refrigerant).
2. ~~Step 2~~Accurately weigh the amount of refrigerant added or removed using an electronic scale.
3. ~~Step 3~~Calculate the refrigerant charge adjustment needed to compensate for non-standard lineset lengths/diameters based on the actual lineset length/diameter and the manufacturer's specifications for adjusting refrigerant charge for non-standard lineset lengths/diameters.

RD~~K~~3.2 Instrumentation Specifications

~~Instrumentation for the procedures described in this section shall conform to the following specifications.~~

~~***3.2.1 Digital Charging Scale***~~

The digital scale used to weigh in refrigerant must have a range of .5 oz to at least 1200 oz (75 lb.). The scale's accuracy must be ± 0.25 oz.

RD~~K~~3.3 Weigh-In Method

The following procedure shall be used by the HVAC installer to charge the system with the correct refrigerant charge.

1. ~~Step 1~~Obtain manufacturer's standard liquid line length and charge adjustment for alternate liquid line lengths.
2. ~~Step 2~~Measure and record the actual liquid line length (L_{actual}).
3. ~~Step 3~~Record the manufacturer's standard liquid line length ($L_{standard}$).
4. ~~Step 4~~Calculate the difference between actual and standard liquid line lengths

   ($L_{actual} - L_{standard}$).
5. ~~Step 5~~Record the manufacturer's adjustment for liquid line length difference per foot (A_{length}).
6. ~~Step 6~~Calculate the amount of refrigerant to add or remove and document the calculations on the CF-6R.
7. ~~Step 7~~Weigh in or remove the correct amount of refrigerant

~~3.4 Airflow Measurement~~

~~The airflow across the indoor evaporator coil shall be measured using one of the 2 methods described Appendix F - Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems:~~

~~Section 4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood~~

~~Section 4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching~~

~~3.5 Adequate Airflow Calculation~~

~~The measured airflow method is used to provide a check to see if airflow is above the required minimum of 385 CFM per nominal ton of capacity (assumes coil is dry). The following steps describe the calculations using the measurement procedure described in Section 3.4. If a system fails, then remedial actions must be taken. The airflow must be re-tested until it passes.~~

~~Step 1.Record the measured airflow ($F_{measured}$) obtained from the measurement procedures described in Section 3.4.~~

~~Step 2.Obtain and record the rated cooling capacity ($C_{cooling}$) in Btu.~~

~~Step 3.Calculate the required airflow as the product of the rated cooling capacity in Btu times 0.032.~~

~~Step 4.Compare the airflow measured according to section 3.4 with the required airflow.~~

~~Step 5.If the measured airflow is greater than the required airflow, then the system **passes** the adequate airflow criteria.~~

~~Step 6.If the measured airflow is less than the required airflow, the system does not pass the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure.~~

Table RD-~~K-~~2~~1~~: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1

Greyed area indicates test conditions where the return drybulb temperature must exceed 70°F

Table RD-~~K-~~2~~1~~: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature) (continued)

	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
Condenser Air Dry-Bulb Temperature (°F)	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Table RD-~~K-~~3~~2~~: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (ºF) ($T_{return, db}$)	Return Air Wet-Bulb (ºF) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

~~APPENDIX D~~

~~The Contents of Appendix D Have Been Deleted.~~

~~Appendix D is Reserved for Future Use for Sample CALRES Test Run Files and Input Descriptions for the Optional Capabilities Tests~~

~~These sample files will be added for information purposes only, and will not be adopted as regulations.~~

ACM RE-2005

Appendix RE – Field Verification and Diagnostic Testing of Forced Air System Fan Flow and Air Handler Fan Watt Draw

NOTE: THIS APPENDIX IS ENTIRELY NEW. THE TRACKED CHANGES REFLECT EDITS TO THE FEB DRAFT AND ARE SHOWN FOR EASE OF REVIEW. THEY WILL NOT BE SHOWN IN THE 45 DAY DRAFT.

RE1. Purpose and Scope

ACM RE-2005 contains procedures for verifying adequate airflow in split system and packaged air conditioning systems serving low-rise residential buildings. The procedure is also used to verify reduced fan watts achieved through improved air distribution design, including more efficient motors and air distribution systems with fewer obstructions. The refrigerant charge test described in ACM RE requires as a prerequisite that adequate airflow be verified. In addition, the reference method algorithms offer a credit for low fan power which can be obtained through diagnostic measurements. Table RE-1 summarizes the diagnostic measurement procedures in ACM RE-2005 and shows their relationship to the equipment efficiency algorithms in ACM Chapter 4.

Table RE-1 – Summary of Diagnostic Measurements

Input to the Algorithms	Variables and Equation Reference	Description	Standard Design Value	Proposed Design: Default Value	Proposed Design: Procedure
Fan Power Ratio	FanW/Btu (Eq. R4-45)	The ratio of fan power in Watts to the cooling capacity in Btu/h.	0.051 W/Btu.	0.051 W/Btu.	Section RE4.4.3
Fan Flow over Evaporator	F_{air} (Eq. R4.42 and R4.43)	The term F_{air} depends on the measured airflow over the evaporator coil. A value of 0.925 is used as a default, but a value of 1.000 can be used if	F_{air} = 1.000 when refrigerant charge testing or TXV is required by Package D.	F_{air} = 0.925	Section RE4.4.1
Refrigerant Charge Prerequisite	n. a.	An airflow of at least 350 cfm/ton must be mained over a wet coil or 400 cfm/ton over a dry coil before a valid refrigerant charge test may be performed	n. a.	n. a.	Section RE4.4.1

RE2. Instrumentation Specifications

The instrumentation for the diagnostic measurements shall conform to the following specifications:

RE2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

RE2.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 7% reading or ± 5 cfm whichever is greater.

RE2.3 Watt Measurements

All measurements of air handler watt draws shall be made with true power measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 2% reading or ± 10 watts whichever is greater.

RE3. Apparatus

RE3.1 System Fan Flows

HVAC system fan flow shall be measured using one of the following methods.

RE3.1.1 Plenum Pressure Matching Measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter) meeting the specifications in RE2.2, a static pressure transducer meeting the specifications in Section RE2.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RE3.1.2 Flow Capture Hood Measurement

A flow capture hood meeting the specifications in Section RE2.2 may be used to verify the fan flow at the return register(s). All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RE3.1.3 Flow Grid Measurement

The apparatus for measuring the system fan flow shall consist of a flow measurement device (subsequently referred to as a fan flow grid) meeting the specifications in RE2.2 and a static pressure transducer meeting the specifications in Section RE2.1. The measuring device shall be attached at a point where all the fan airflow shall flow through the flow grid. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RE3.2 Air Handler Watts

The air handler watt draw shall be measured using one of the following methods.

RE3.2.1 Portable Watt Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of a watt meter meeting the specifications in RE3.1.3. The measuring device shall be attached to measure the air handler fan watt draw. All registers shall be in their normal operating condition.

RE3.2.2 Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the utility revenue meter meeting the specifications in RE3.1.3 and a stopwatch measuring in seconds. All registers shall be in their normal operating condition.

RE4. Procedure

To determine and verify airflow credit a diagnostic fan flow measurement shall demonstrate air flow greater than the criteria and installation of the duct system must be designed to meet the criteria in RE4.2.

To determine and verify airflow and fan watt draw credit, in addition to verifying air flow, the air handler fan watt draw measurement shall show fan watts less than that claimed in ACM calculations and shown in CF-1R.

RE4.1 Diagnostic Fan Flow

Table RE-2 – Airflow Criteria

Note: All airflows are for the fan set at the speed used for air conditioning.

Test and Condition	Cooling air flow (Wet Coil)	Test Flow if Dry Coil
Airflow needed for compliance credit	400 cfm/ton	450 cfm/ton

The system passes the fan flow test if the fan flow measured using one of the following methods is greater than the criteria in Table RE2. The Wet Coil criteria shall be used if the air conditioner is operating and conditions are such that the coil is wet. Otherwise the Dry coil criteria shall be used

RE4.1.1 Diagnostic Fan Flow Using Flow Capture Hood

The fan flow measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan flow at the return grille(s) with a calibrated flow capture hood to determine the total system return fan flow. The system fan flow (Qah, cfm) shall be the sum of the measured return flows.

RE4.1.2 Diagnostic Fan Flow Using Plenum Pressure Matching

The fan flow measurement shall be performed using the following procedures:

1. If the fan flowmeter is to be connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.
2. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). Psp is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.3. Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.
3. Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose.
4. Turn on the system fan and the fan flow meter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches Psp.
5. Record the flow through the flowmeter (Qah, cfm) - this is the diagnostic fan flow. In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach Psp. In this case record the maximum flow (Qmax, cfm) and pressure (Pmax) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Qmax and Pmax) to operating condition at operating pressure (Psp).

   Equation RE-1 Air Handler Flow Qah = Qmax x (Psp/Pmax) ^.5

RE4.1.3 Diagnostic Fan Flow Using Flow Grid Measurement

The fan flow measurement shall be performed using the following procedures:

1. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.
2. The flow grid shall be attached at a point where all the fan air flows through the flow grid.
3. Re-measure the system operating pressure with the flow grid in place.

4. Measure the air flow through the flow grid (Qgrid) and the test pressure (Ptest).

5. The following equation for air handler flow shall be used to correct flow through the flow grid and pressure (Qgrid and Ptest) to operating condition at operating pressure (Psp).

Equation RE-2 Qah = Qmax x (Psp/Ptest) ^.5

RE4.2 Duct Design

The duct system installation shall be verified to be consistent with the design meeting the following requirements. The duct system shall be designed to meet the airflow rate with the available external static pressure from the air handler at that airflow. The duct design shall have calculations showing the duct system will operate at equal to or greater than 0.0375 cfm/Btu rated capacity at ARI test condtions (450 cfm/12000 Btu) in cooling speed (dry coil) or, if heating only, equal to or greater than 16.8 cfm per 1000 Btu/hr furnace output. The design shall be based on the available external static pressure from the air handler, the pressure drop of external devices, the equivalent length of the runs, as well as the size, type and configuration of the ducts. The duct layout shall be included on the plans and the duct design shall be reported on the CF-6R and posted on-site.

RE4.3 Diagnostic Air Handler Watt Draw

The system passes the Watt Draw test if the air handler watt draw is less than or equal to the value claimed in compliance calculations and reported by the ACM on the CF-1R. The diagnostic air handler watt draw shall be measured using one of the following methods:

RE4.3.1 Diagnostic Air Handler Watt Draw Using Portable Watt Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan watt draw (Wfan).

RE4.3.2 Diagnostic Air Handler Watt Draw Using Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and turn off every circuit breaker except the one exclusively serving the air handler. Record the Kh factor on the revenue meter, count the number of full revolutions of the meter wheel over a period exceeding 90 seconds. Record the number of revolutions (Nrev) and time period (trev, seconds). Compute the air handler watt draw (Wfan) using the following formula:

Equation RE-3 Air Handler Fan Watt Draw Wfan = (Kh x Nrev x 3600) / trev

Return all circuit breakers to their original positions.

~~APPENDIX E~~

~~This appendix is provided to accept Commission Approved descriptions of framing assemblies. These assembly descriptions are in Appendix B of the Nonresidential ACM Manual.~~

ACM RF-2005

Appendix RF – HVAC Sizing

NOTE: THIS APPENDIX IS ENTIRELY NEW. THE TRACKED CHANGES SHOWN REFLECT EDITS TO THE FEB DRAFT AND ARE SHOWN FOR EASE OF REVIEW. THEY WILL NOT APPEAR IN THE 45 DAY DRAFT.

RF1. Purpose and Scope

ACM RF-2005 is a procedure for calculating the cooling load in low-rise residential buildings (Section RF2) and for determining the maximum cooling capacity for credit in ACM calculations (Section RF3). Section RF4 has a procedure for determining compliance for oversized equipment by showing that the peak power is equal to or less than equipment that minimally meet the requirements of this section.

RF2. Procedure for Calculating Design Cooling Capacity

The following rules apply when calculating the design cooling:

RF2.1 Methodology

The methodologies, computer programs, inputs, and assumptions approved by the commission shall be used.

RF2.2 Cooling Loads

Except as specified in this section, calculations will be done in accordance with the method described in Chapter 28, Residential Cooling and Heating Load Calculations, 2001 ASHRAE Fundamentals Handbook. Interpolation shall be used with tables in Chapter 28. The methods in Chapter 29 may not be used under this procedure.

RF2.3 Indoor Design Conditions

The indoor cooling design temperature shall be 75°F. An indoor design temperature swing of 3°F shall be used.

RF2.4 Outdoor Design Conditions

Outdoor design conditions shall be selected from the 1.0 Percent Cooling Dry Bulb and Mean Coincident Wet Bulb values in Joint Appendix II REF

RF2.5 Block Loads

The design cooling capacity used for calculating the maximum allowable cooling capacity is based on the block (peak) load either for

1. The whole building; or
2. For each zone within a building that is served by its own cooling system; or
3. For each dwelling unit within a building that is served by its own cooling system.

Room-by-room loads are not allowed for calculating the design cooling capacity.

RF2.6 Table Selection

Tables 2 (cooling load temperature differences) and 4 (glass load factors) shall be used for:

1. Buildings with more than one dwelling unit using whole building block loads; or
2. Buildings or zones with either east or west exposed walls but not both east and west exposed walls.

Otherwise, Tables 1 (cooling load temperature differences) and 3 (glass load factors) shall be used.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF2.7 U-factors

U-factors for all opaque surfaces and fenestration products shall be consistent with the methods described in Section 4.2 and Section 4.3 of the Residential ACM Manual. The effects of radiant barriers or cool roofs shall be included if these features are in the proposed building.

RF2.8 Solar Heat Gain Coefficients

Solar heat gain coefficients (SHGC) shall be equal to the $SHGC_{closed}$ values described in Section 4.3.4 of the Residential ACM Manual.

RF2.9 Glass Load Factors

Glass load factors (GLFs) shall be calculated using the equation in the footnotes of Tables 3 and 4 in Chapter 28 using the columns for “Regular Double Glass” and the rows for “Draperies, venetian blinds, etc”. The table values used in the equation shall be $U_t = 0.55$ and $SC_t = 0.45$. The shading coefficient for the alternate value shall be SC_a = SHGC x 0.87 where the SHGC value is described above. The GLF values shall also be adjusted for latitude as described in the footnotes.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF2.10 Infiltration

The air flow (CFM) due to infiltration and mechanical ventilation shall be calculated with the effective leakage area method as documented in Section 4.5.1 of the Residential ACM Manual using the outdoor design temperature minus the indoor design temperature as the temperature difference and a 7.5 mph wind speed.

RF2.11 Internal Gain

Occupancy shall be assumed to be two persons for the first bedroom and one person for each additional bedroom per dwelling unit. Each person shall be assigned a sensible heat gain of 230 Btu/hr. Appliance loads shall be 1200 Btu/hr for multifamily buildings with common floors and ceilings. Otherwise the appliance load is 1600 Btu/hr.

RF2.12 Cooling Duct Efficiency

The cooling duct efficiency shall be calculated using the seasonal approach as documented in ACM RB-2005.

RF2.13 Latent Factor.

The latent factor shall be 1.0.

RF2.14 Total Cooling Load

The total cooling load is calculated in accordance with Table 9 of Chapter 28 with the values specified in this section.

RF2.15 Design Cooling Load

The design cooling load is equal to the total cooling load divided by the cooling duct efficiency.

RF2.16 Design Cooling Capacity

The design cooling capacity calculation adjusts the sensible design cooling load to estimate the rated cooling capacity needed as follows:

Equation RF-1

$$\text{Design Cooling Capacity (Btu/hr)} = \frac{\text{Design Cooling Load (Btu/hr)}}{(0.88\ \ (0.002286 \text{ x } (\text{Outdoor Cooling Design Temperature } (°\ \ 95)))}$$

RF3. Procedure for Calculating Maximum Cooling Capacity for ACM Credit

The following rules apply when calculating the maximum cooling capacity for ACM credit:

RF3.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF3.2 Maximum Cooling Capacity for ACM Credit

For buildings with a single cooling system or for buildings where the design cooling capacity has been calculated separately for each cooling system, the maximum cooling capacity for ACM credit for each cooling system shall be:

Table RF-1 – Maximum Cooling Capacity for ACM Credit

Design Cooling Capacity (Btu/hr)		Maximum Cooling Capacity for ACM Credit (Btu/hr)
< 48000		Design Cooling Capacity + 6000
48000 - 60000		Design Cooling Capacity + 12000
>60000		Design Cooling Capacity + 30000

For buildings with more than one cooling system where the design cooling capacity has been calculated for the entire building, the maximum cooling capacity for ACM credit for the entire building shall be:

Equation RF-2

$$\text{Maximum Cooling Capacity for ACM Credit (Btu/hr)} = \text{Design Cooling Capacity (Btu/hr)} + (6000 \text{ (Btu/hr) x Number of Cooling Systems})$$

RF3.3 Multiple Orientations

For buildings demonstrating compliance using the multiple orientation alternative of Section 151(c), the maximum cooling capacity for ACM credit is the highest of the four cardinal orientations. For buildings with more than cooling system, the orientation used for determining the maximum cooling capacity for ACM credit shall be permitted to be different for each zone.

RF4. Procedure for Determining Electrical Input Exception for Maximum Cooling Capacity for ACM Credit

The installed cooling capacity shall be permitted to exceed the maximum cooling capacity for ACM credit if the electrical input of the oversized cooling system is less than or equal to the electrical input of a standard cooling system using the following rules:

RF4.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF4.2 Standard Total Electrical Input

The standard electrical input is calculated as follows:

Equation RF-3

$$\text{Standard Total Electrical Input (W)} = 0.1170.1048 \text{ (W/Btu/hr) x Design Cooling Capacity (Btu/hr)}$$

RF4.3 Proposed Electrical Input

The proposed electrical input (W) for the installed cooling system is calculated as follows:

Equation RF-4

$$\text{Proposed Compressor Electrical Input (W)} = \text{Electrical Input (W) - (.0122 * Design Cooling Capacity (Btu/hr))}$$

Where "Electrical Input" is as published in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

The proposed electrical input (W) for the installed cooling system is published as the "Electrical Input" in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

RF4.4 Proposed Fan Power

The proposed fan power (W) of the installed cooling system is equal to either:

1. 0.017 (W/Btu/hr) x Design Cooling Capacity (Btu/hr); or
2. The measured fan power (W) where the measured fan power is determined using the procedure described in ACM RE-2005 of the *Residential ACM Manual*.

RF4.5 Proposed Total Electrical Input

The proposed electrical input is equal to:

Equation RF-5

$$\text{Proposed Total Electrical Input (W)} = \text{Proposed Electrical Input (W)} + \text{Proposed Fan Power (W)}$$

For buildings with more than one cooling system, the proposed total electrical power shall be the sum of the values for each system. If the proposed total electrical input is less than or equal to the standard total electrical input, then the installed cooling capacity may exceed the allowable cooling capacity for ACM credit.

~~APPENDIX F~~

~~Appendix F~~

~~*Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems*~~

~~*1.0 Introduction*~~

~~This appendix describes the measurement and calculation methods for determining air distribution system efficiency.~~

~~*2.0 Definitions*~~

~~***aerosol sealant closure system***: A method of sealing leaks by blowing aerosolized sealant particles into the duct system and which must include minute-by-minute documentation of the sealing process.~~

~~***floor area :***The floor area of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces enclosing the conditioned space.~~

~~***delivery effectiveness :***The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.~~

~~***distribution system efficiency :***The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.~~

~~***equipment efficiency :***The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.~~

~~***equipment factor*** : F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.~~

~~***fan flowmeter device***: A device used to measure air flow rates under a range of test pressure differences.~~

~~***flowhood:*** A device used to capture and measure the airflow at a register.~~

~~***load factor*** : F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.~~

~~***pressure pan*** : a device used to seal individual forced air system registers and to measure the static pressure from the register.~~

~~***radiant barrier*** : a surface of low emissivity (less than 0.05) placed inside an attic or roof space to reduce radiant heat transfer.~~

~~***recovery factor*** : F_{recov} is the fraction of energy lost from the distribution system that enters the conditioned space.~~

~~***thermal regain:*** The fraction of delivery system losses that are returned to the building.~~

~~*3.0 Nomenclature*~~

~~a_r = duct leakage factor (1-return eakage) for return ducts~~

~~a_s = duct leakage factor (1-supply leakage)p for supply ducts~~

~~A_{floor} = conditioned floor area of building , ft^2~~

~~$A_{r,out}$ = surface area of return duct outside conditioned space ,ft^2~~

~~$A_{r,attic}$ = return duct area in attic , ft^2~~

~~$A_{r,base}$ = return duct area in basement , ft^2~~

~~$A_{r,crawl}$ = return duct area in crawlspace, ft^2~~

~~$A_{r,gar}$ = return duct area inside garage, ft^2~~

~~$A_{s,out}$ = surface area of supply duct outside conditioned space,ft^2~~

~~$A_{s,attic}$ = supply duct area in attic , ft^2~~

~~$A_{s,base}$ = supply duct area in basement , ft^2~~

~~$A_{s,crawl}$ = supply duct area in crawlspace,ft^2~~

~~$A_{s,gar}$ = supply duct area inside garage, ft^2~~

~~$A_{s,in}$ = supply duct area inside conditioned space, ft^2~~

~~B_r = conduction fraction for return~~

~~B_s = conduction fraction for supply~~

~~DE = delivery effectiveness_~~

~~DE_{design} = design delivery effectiveness~~

~~$DE_{seasonal}$ = seasonal delivery effectiveness~~

~~E_{equip} = rate of energy exchanged between equipment and delivery system, Btu/hour~~

~~$F_{cycloss}$ = cyclic loss factor~~

~~F_{equip} = load factor for equipment~~

~~F_{flow} = load factor for fan flow effect on equipment efficiency~~

~~F_{leak} = fraction of system fan flow that leaks out of supply or return ducts~~

~~F_{load} = load factor for delivery system~~

~~F_{recov} = thermal loss recovery factor~~

~~F_{regain} = thermal regain factor~~

~~K_r = return duct surface area coefficient~~

~~K_s = supply duct surface area coefficient~~

~~N_{story} = number of stories of the building~~

~~P_{sp} = pressure difference between supply plenum and conditioned space [Pa]~~

~~P_{test} = test pressure for duct leakage [Pa]~~

~~Q_e = Flow through air handler fan at operating conditions, cfm~~

~~$Q_{total,25}$ = total duct leakage at 25 Pascal, cfm~~

~~R_r = thermal resistance of return duct, h ft^2 F/Btu~~

~~R_s = thermal resistance of supply duct, h ft^2 F/Btu~~

~~$T_{amb,r}$ = ambient temperature for return , F~~

~~$T_{amb,s}$ = ambient temperature for supply , F~~

~~T_{attic} = attic air temperature , F~~

~~T_{base} - return duct temperature in basement, F~~

~~T_{crawl} - return duct temperature in crawlspace,F~~

~~T_{design} = outdoor air design temperature , F~~

~~T_{ground} = ground temperature , F~~

~~T_{gar} = temperature of garage air , F~~

~~T_{in} = temperature of indoor air , F~~

~~T_{rp} = return plenum air temperature , F~~

~~$T_{seasonal}$ = outdoor air seasonal temperature, F~~

~~T_{sp} = supply plenum air temperature , F~~

~~ΔT_e = temperature rise across heat exchanger , F~~

~~ΔT_r = temperature difference between indoors and the ambient for the return , F~~

~~ΔT = temperature difference between indoors and the ambient for the supply,~~

~~$\eta_{dist,seasonal}$ = seasonal distribution system efficiency~~

~~*4.0 Air Distribution Diagnostic Measurement and Default Assumptions*~~

~~4.1 Instrumentation Specifications~~

~~The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:~~

~~4.1.1 Pressure Measurements~~

~~All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.~~

~~4.1.2 Fan Flow Measurements~~

~~All measurements of distribution fan flows shall be made with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ±5% reading or ±5 cfm whichever is greater.~~

~~4.1.3 Duct Leakage Measurements~~

~~The measurement of air flows during duct leakage testing shall have an accuracy of ±3% of measured flow using digital gauges.~~

~~All instrumentation used for fan flow and duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.~~

~~*4.2 Apparatus*~~

~~4.2.1 System Fan Flows~~

~~HVAC system fan flow shall be measured using one of the following methods.~~

~~4.2.1.1 Plenum pressure matching measurement~~

~~The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter [see section 4.3.7.2.2.]) meeting the specifications in 4.1.3, a static pressure transducer meeting the specifications in Section 4.1.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower~~

~~compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.~~

~~4.2.1.2 Flow hood measurement~~

~~A flow hood meeting the specifications in section 4.1.2. can be used to verify the fan flow at the return register(s) after the completion of a rough-in duct leakage measurement. All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).~~

~~4.2.2 Duct Leakage~~

~~The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section 4.1.3.~~

~~*4.3 Procedure*~~

~~The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.~~

~~4.3.1 Building Information~~

~~The calculation procedure for determining air distribution efficiencies requires the following building information:~~

~~1.climate zone for the building,~~

~~2.conditioned floor area,~~

~~3.number of stories,~~

~~4.supply duct location and~~

~~5.floor type.~~

~~4.3.1.1 Default Input~~

~~Using default values rather than diagnostic procedures produce relatively low air distribution-system efficiencies. Default values shall be obtained from following sections:~~

1. ~~the location of the duct system in Section 4.3.4,~~
2. ~~the surface area and insulation level of the ducts in Sections 4.3.3, 4.3.4 and 4.3.6,~~
3. ~~the system fan flow in Section 4.3.7, and~~
4. ~~the leakage of the duct system in Section 4.3.8.~~

~~4.3.2 Diagnostic Input~~

~~Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described in~~

~~Sections 4.3.5 through 4.3.8. These observations and measurements replace those assumed as default values.~~

~~The diagnostic procedures include~~

- ~~measure supply duct surface area as described in Section 4.3.3.2.~~
- ~~measure total duct system leakage as described in Section 4.3.8.~~
- ~~measure system fan flow or observe the presence of a thermostatic expansion valve for claiming ACCA manual D design credit as described in Section 4.3.7.~~
- ~~Observe the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section 4.3.6.~~
- ~~Observe the presence of radiant barriers.~~

~~4.3.3 Duct Surface Area~~

~~The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one zone, the area of that duct in each zone shall be calculated separately. The duct surface area shall be determined using the following methods.~~

~~4.3.3.1 Default Duct Surface Area~~

~~4.3.3.1.1 Duct Surface Area for More Than 12 feet of Duct Outside Conditioned Space~~

~~The default duct surface area for supply and return shall be calculated as follows:~~

~~For supplies:~~

$$\cancel{A_{s,total} = 0.27 A_{floor} \quad (4.1)}$$

~~For returns:~~

$$\cancel{A_{r,total} = K_r \; A_{floor} \quad (4.2)}$$

~~Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.~~

~~4.3.3.1.1 Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space~~

~~For HVAC systems with air handlers located outside the conditioned space but with less than 12 feet of duct located outside the conditioned space including air handler and plenum, the duct surface area outside the conditioned space shall be calculated as follows:~~

~~$A_{s,out} = 0.027\ A_{floor}$ (4.3)~~

~~Where $A_{s,out}$ is substituted for $A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$ depending on the location of the ducts.~~

~~4.3.3.2 Diagnostic Duct Surface Area~~

~~A well designed duct system can reduce the length of the supply duct. Smaller duct surface area will result in reduced duct conduction losses. Duct surface area shall be calculated from measured duct lengths and nominal outside diameters (for round ducts) or outside perimeters (for rectangular ducts) of each duct run in the building. Improved conduction losses can be claimed for reduced supply duct surface area only (it does not apply to the return duct). Supply plenum surface area shall be included in the supply duct surface area. Diagnostic duct surface area requires measuring duct surface areas separately for each location outside conditioned space ($A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$) and the system fan flow to ensure that there is sufficient air flow to deliver the designed heating and cooling loads.~~

~~4.3.4 Duct Location~~

~~Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Default duct surface areas by locations of the supply duct shall be obtained from Table 4.1. The default duct surface area for crawlspace and basement applies only to buildings with all supply ducts installed in the crawlspace or basement. If the supply duct is installed in locations other than crawlspace or basement, the default supply duct location shall be "Other".~~

~~If ducts are installed in multiple locations, air distribution efficiency shall be calculated for each duct location. Total air distribution efficiency for the house shall be the weighted average based on the floor area served by each duct system.~~

~~**Table 4.1 Default Assumptions for Duct Locations**~~

	~~**Supply Duct Surface Area**~~		~~**Return Duct Surface Area**~~	
~~Supply or Return Duct Location~~	~~One story~~	~~Two or more story~~	~~One story~~	~~Two or more story~~
~~Attic~~	~~100% attic~~	~~65% attic 35% conditioned space~~	~~100% attic~~	~~100% attic~~
~~Crawlspace~~	~~100% crawlspace~~	~~65% crawlspace 35% conditioned space~~	~~100% attic~~	~~100% attic~~
~~Basement~~	~~100% Basement~~	~~65% basement 35% conditioned space~~	~~100% Basement~~	~~100% Basement~~
~~Other~~	~~100% attic~~	~~65% attic 35% conditioned space~~	~~100% attic~~	~~100% attic~~

~~4.3.5 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space~~

~~Duct ambient temperature for both heating and cooling at different duct locations shall be obtained from Table 4.2. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be~~

~~applied to cooling calculations. The procedures for the installation of radiant barriers shall be as described in ACM Section 4.23. Attic temperatures for houses with radiant barriers shall be obtained from Table 4.2.~~

~~*Table 4.2 Default Assumptions for Duct Ambient Temperature*~~

	~~Duct Ambient Temperature for Heating, $T_{heat,amb}$~~			~~Duct Ambient Temperature for Cooling, $T_{cool,amb}$~~				
~~Climate zone~~	~~Attic~~	~~Crawlspace~~	~~Basement~~	~~Attic~~	~~Attic w/ radiant barrier (supply)~~	~~Attic w/ radiant barrier (return)~~	~~Crawlspace~~	~~Basement~~
~~1~~	~~52.0~~	~~52.2~~	~~48.9~~	~~60.0~~	~~65.4~~	~~61.2~~	~~54.0~~	~~49.1~~
~~2~~	~~48.0~~	~~48.7~~	~~56.5~~	~~87.0~~	~~84.3~~	~~84.2~~	~~78.0~~	~~64.5~~
~~3~~	~~55.0~~	~~54.9~~	~~58.3~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~62.8~~
~~4~~	~~53.0~~	~~53.1~~	~~56.6~~	~~79.0~~	~~78.7~~	~~77.4~~	~~70.9~~	~~61.4~~
~~5~~	~~49.0~~	~~49.6~~	~~52.3~~	~~74.0~~	~~75.2~~	~~73.1~~	~~66.4~~	~~56.8~~
~~6~~	~~57.0~~	~~56.7~~	~~59.9~~	~~81.0~~	~~80.1~~	~~79.1~~	~~72.7~~	~~64.1~~
~~7~~	~~62.0~~	~~61.1~~	~~60.4~~	~~74.0~~	~~75.2~~	~~73.1~~	~~66.4~~	~~61.6~~
~~8~~	~~58.0~~	~~57.6~~	~~60.1~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~63.9~~
~~9~~	~~53.0~~	~~53.1~~	~~59.6~~	~~87.0~~	~~84.3~~	~~84.2~~	~~78.0~~	~~66.4~~
~~10~~	~~53.0~~	~~53.1~~	~~61.1~~	~~91.0~~	~~87.1~~	~~87.6~~	~~81.6~~	~~68.9~~
~~11~~	~~48.0~~	~~48.7~~	~~59.5~~	~~95.0~~	~~89.9~~	~~91.0~~	~~85.1~~	~~69.5~~
~~12~~	~~50.0~~	~~50.4~~	~~59.3~~	~~91.0~~	~~87.1~~	~~87.6~~	~~81.6~~	~~67.8~~
~~13~~	~~48.0~~	~~48.7~~	~~58.4~~	~~92.0~~	~~87.8~~	~~88.4~~	~~82.4~~	~~67.6~~
~~14~~	~~39.0~~	~~40.7~~	~~55.4~~	~~99.0~~	~~92.7~~	~~94.4~~	~~88.7~~	~~68.6~~
~~15~~	~~50.0~~	~~50.4~~	~~63.4~~	~~102.~~	~~94.8~~	~~96.9~~	~~91.3~~	~~74.6~~
~~16~~	~~32.0~~	~~34.4~~	~~43.9~~	~~80.0~~	~~79.4~~	~~78.2~~	~~71.8~~	~~54.1~~

~~4.3.6 Duct Wall Thermal Resistance~~

~~*4.3.6.1 Default Duct Insulation R value*~~

~~Default duct wall thermal resistance is R4.2. An air film resistance of 0.7 [h ft^2-ºF/BTU] shall be added to the duct insulation R value to account for external and internal film resistance.~~

~~*4.3.6.2 Diagnostic Duct Wall Thermal Resistance*~~

~~Duct wall thermal resistance shall be determined from the manufacturer's specification observed during diagnostic inspection. If ducts with multiple R values are installed, the lowest duct R value shall be used. If a duct with a higher R value than 4.2 is installed, the R-value shall be clearly stated on the building plan and a visual inspection of the ducts must be performed to verify the insulation values. In case the space on top of~~

~~the duct boot is limited and can not be inspected, the insulation R value within two feet of the boot to which the duct is connected may be excluded from the determination of the overall system R value.~~

~~4.3.7 System Fan Flow~~

~~*4.3.7.1 Default Fan Flow*~~

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for **climate zones 8 through 15** shall be calculated as follows:~~

$$\cancel{Q_e = 0.70\ A_{floor}} \quad \cancel{(4.4)}$$

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for **climate zones 1 through 7 and 16** and default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:~~

$$\cancel{Q_e = 0.50\ A_{floor}} \quad \cancel{(4.5)}$$

~~*4.3.7.2 Diagnostic Fan Flow*~~

~~To obtain duct efficiency credit for duct systems designed according to ACCA Manual D, a diagnostic fan flow measurement must be performed or the installation of a thermostatic expansion valve must be verified. The access panel on the cooling coil shall be removable for the verification of a thermostatic expansion valve. For ACCA Manual D designed duct system, engineering calculations and the building plan for duct sizing and layout shall also be prepared. The diagnostic fan flow measurement shall be measured using one of the following methods:~~

~~*4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood:*~~

~~To measure the system return fan flow, all registers shall be fully open, and the air filter shall be installed. Turn on the system fan and measure the fan flow at the return grille(s) with a calibrated flow hood to determine the total system return fan flow. The system fan flow (Q_e) shall be the sum of the measured return flows.~~

~~*4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching:*~~

~~The fan flow measurement shall be performed using the following procedures:~~

1. ~~With the system fan on (in heating mode with burners on for heating, or in cooling mode with compressor on), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (ΔP_{sp}). P_{sp} is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.~~

~~2. Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.~~

~~3. Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose. Assure that there is no significant leakage between the fan flowmeter and the system fan.~~

~~4. If the fan flowmeter is connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.~~

~~5. Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches~~ $\cancel{P_{sp}}$~~.~~

~~6. Record the flow through the flowmeter (~~$\cancel{Q_e}$~~, cfm) - this is the diagnostic fan flow.~~

~~In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach~~ $\cancel{P_{sp}}$~~. In this case record the maximum flow (~~$\cancel{Q_{max}}$~~, cfm) and pressure (~~$\cancel{P_{max}}$~~) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (~~$\cancel{Q_{max}}$ ~~and~~ $\cancel{P_{max}}$~~) to operating condition (~~$\cancel{Q_e}$~~) at operating pressure (~~$\cancel{P_{sp}}$~~).~~

$$\cancel{Q_e = Q_{max}\left(\frac{P_{sp}}{P_{max}}\right)^{\frac{1}{2}} \qquad (4.6)}$$

~~4.3.8 Duct Leakage~~

~~*4.3.8.1 Duct Leakage Factor for Delivery Effectiveness Calculations*~~

~~Default duct leakage factors shall be obtained from Table 4.3, using the “not Tested” values.~~

~~Duct leakage factors shown in Table 4.3 shall be used in calculations of delivery effectiveness.~~

~~**Table 4.3 Duct Leakage Factors**~~		
	~~Duct Leakage Diagnostic Test Performed using Section 4.3.8.2 Procedures~~	~~$a_s = a_r =$~~
~~Duct systems in homes built prior to 1999~~	~~Not tested~~	~~0.86~~
~~Duct systems in homes built after 1999~~	~~Not tested~~	~~0.89~~
~~*Duct systems in homes of all ages, System with refrigerant based cooling, tested after house and HVAC system completion*~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{ecool}~~	~~0.96~~
~~Duct systems in homes of all ages, System without refrigerant based cooling, tested after house and HVAC system completion~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{eheat}~~	~~0.96~~
~~Duct systems with refrigerant based cooling, in homes built after 1999,~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{ecool}~~	~~0.96~~

~~System tested with air handler installed, but prior to installation of the interior finishing wall~~	~~and final duct integrity verified~~	
~~Duct systems without refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.06 Q_{eheat} and final duct integrity verified~~	~~0.96~~
~~Duct systems with refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.04 Q_{ecool} and final duct integrity verified~~	~~0.96~~
~~Duct systems without refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall~~	~~(Q_{25}) Total leakage is less than 0.04 Q_{eheat} and final duct integrity verified~~	~~0.96~~

~~*4.3.8.2 Diagnostic Duct Leakage*~~

~~Diagnostic duct leakage measurement is used to quantify total leakage for the calculation of air distribution efficiency. To obtain the improved duct efficiency for sealing the duct system, a diagnostic leakage test as described in section 4.3.8.2.1 or 4.3.8.2.2 must be performed. Houses built after 1/1/1999 shall not be allowed to claim duct leakage credit and diagnostic testing may not be done on any HVAC system that uses building cavities such as plenums or a platform return.~~

~~*4.3.8.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts*~~

~~The total duct leakage shall be determined by pressurizing the ducts to 25 Pascals. The following procedure shall be used for the fan pressurization tests:~~

~~1. Seal all the supply and return registers, except for one return register or the system fan access.~~

~~2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.~~

~~3. Install a static pressure probe at a supply.~~

~~4. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.~~

~~5. Record the flow through the flowmeter ($Q_{total,25}$) - this is the total duct leakage flow at 25 Pascals.~~

~~When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table 4.3.~~

~~*4.3.8.2.2 Diagnostic Duct Leakage at Rough-in Construction Stage Using An Aerosol Sealant Closure System*~~

~~Duct leakage in new construction may be determined by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing wall when using an aerosol sealant closure system. When using this measurement technique, additional verification (as described in section~~

~~4.3.8.2.2.3) of duct integrity shall be completed after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.~~

~~The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The procedures in Sections 4.3.8.2.2.1 and 4.3.8.2.2.2 shall be used for measuring duct leakage before the interior finishing wall is installed.~~

~~4.3.8.2.2.1 For ducts with the air handling unit installed and connected:~~

~~For total leakage:~~

~~1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.~~

~~2. Seal all the supply duct boots and return boxes except for one return duct box.~~

~~3. Attach the fan flowmeter device at the unsealed duct box.~~

~~4. Insert a static pressure probe at one of the sealed supply duct boots.~~

~~5. Adjust the fan flowmeter to maintain 25 Pa(0.1 in water)between the duct system and outside or the building space with the entry door open to the outside.~~

~~6. Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa at rough-in stage.~~

~~7. Divide the measured total leakage by the total fan flow calculated from equation 4.4 or 4.5.~~

~~If the total leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table 4.3.~~

~~4.3.8.2.2.2 For ducts with air handling unit not yet installed:~~

~~For total leakage:~~

~~1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.~~

~~2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.~~

~~3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.~~

~~4. Attach the fan flowmeter device at the unsealed duct box.~~

~~5. Insert a static pressure probe at one of the sealed supply duct boots.~~

~~6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.~~

~~7. Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa.~~

~~8. Divide the measured total leakage by the total fan flow calculated from equation 4.4 or 4.5. If the total leakage is less than 4% of the total fan flow, the total duct leakage factor shall be 0.96 as shown in Table 4.3.~~

~~*4.3.8.2.2.3 Post rough-in duct leakage verification*~~

~~After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, one of the following post rough-in verification tests shall be performed to ensure that there is no major leakage in the duct system.~~

~~*4.3.8.2.2.3.1 Visual inspection*~~

~~Remove at least one supply and one return register to verify that the spaces between the register boot and the interior finishing wall are properly sealed. In addition, if the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.~~

~~*4.3.8.2.2.3.2 Pressure pan test*~~

~~With register dampers fully open, the house is pressurized to 25 pascals by a blower door, (If two registers are within 5 feet of each other and are connected to the same duct run, one register shall be sealed off before the pressure pan test is performed). the pressure difference across each register shall not exceed 1.5 Pa.~~

~~*4.3.8.2.2.3.3 House Pressure Test*~~

~~The pressure difference between the building conditioned space and a vented attic shall be measured to determine whether the house pressure is changed appreciably by the operation of the air handler. To perform this test, the pressure difference~~ $\cancel{(P_{house} - P_{out})}$ ~~between the building conditioned space and a vented attic (or outside if impossible to access the attic), shall be measured four times:~~

~~1. with the fan off~~ $\cancel{(\Delta P_{off1})}$

~~2. with the fan on~~ $\cancel{(\Delta P_{on})}$

~~3. with the fan on and the return grille 80% blocked~~ $\cancel{(\Delta P_{RB})}$~~. Block 80% on all return grilles if the house has two or more returns.~~

~~4. with the fan off~~ $\cancel{(\Delta P_{off2})}$

~~For each of these measurements, the five-second average pressure shall be measured 10 times and these 10 measurements shall be averaged.~~

~~For the house to pass this test, the following conditions must be true:~~

~~1.~~ $\cancel{\Delta P_{on} - (\Delta P_{off2} + \Delta P_{off1})/2}$ ~~must be between +0.8 Pa and -0.8 Pa and~~

~~2~~ $\cancel{\Delta P_{RB} - \Delta P_{on}}$ ~~must be less than 0.8 Pa.~~

~~In addition, the absolute value of~~ $\cancel{(\Delta P_{off2} - \Delta P_{off1})}$ ~~must be less than 0.25 Pa, or else the test must be repeated. If the repeated test does not meet the above specified values, visual inspection or the pressure pan test or the fan pressurization test must be used. If these tests fail, the duct system needs to be properly sealed and re-verified by a fan pressurization test.~~

~~*4.4 Delivery Effectiveness (DE) Calculations*~~

~~Seasonal delivery effectiveness shall be calculated using the seasonal design temperatures from Tables 4.2.~~

~~4.4.1 Calculation of Duct Zone Temperatures~~

~~The temperatures of the duct zones outside the conditioned space are determined in Section 4.3.5 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures:~~

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)\,T_{attic} + A_{s,crawl}\,T_{crawl} + A_{s,base}\,T_{base}}{A_{s,out} + 0.001} \quad (4.7)$$

$$T_{amb,r} = \frac{A_{r,attic}\,T_{attic} + A_{r,crawl}\,T_{crawl} + A_{r,base}\,T_{base}}{A_{r,out}} \quad (4.8)$$

~~The return ambient temperature, $T_{amb,r}$, shall be limited as follows:~~

~~For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$. For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.~~

$$T_{amb,r} = \frac{T_{design} - 16^{o}F + \dfrac{\sum\limits_{i=\text{duct location}}^{\substack{\text{all return duct locations}\\ \text{outside conditioned space}}} A_i T_i}{A_r}}{2} \quad (4.20b)$$

~~4.4.2 Seasonal Delivery Effectiveness (DE)~~

~~The supply and return conduction fractions, B_s and B_r, shall be calculated as follows:~~

$$\cancel{B_s = \exp\left(\frac{-A_{s,out}}{1.08\,Q_e\,R_s}\right) \quad (4.9)}$$

$$\cancel{B_r = \exp\left(\frac{-A_{r,out}}{1.08\,Q_e\,R_r}\right) \quad (4.10)}$$

~~The temperature difference across the heat exchanger in the following equation is used:~~

~~for heating:~~

$$\cancel{\Delta T_e = 55} \quad \cancel{(4.11)}$$

~~for cooling:~~

$$\cancel{\Delta T_e = -20} \quad \cancel{(4.12)}$$

~~The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r, shall be calculated using the indoor and the duct ambient temperatures.~~

$$\cancel{\Delta T_s = T_{in} - T_{amb,s}} \quad \cancel{(4.13)}$$

$$\cancel{\Delta T_r = T_{in} - T_{amb,r}} \quad \cancel{(4.14)}$$

~~The seasonal delivery effectiveness for heating or cooling systems shall be calculated using:~~

$$\cancel{DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}} \quad \cancel{(4.15)}$$

~~1~~

~~*4.5 Seasonal Distribution System Efficiency*~~

~~Seasonal distribution system efficiency shall be calculated using delivery effectiveness, equipment, load, and recovery factors calculated for seasonal conditions.~~

~~4.5.1 Equipment Efficiency Factor (F_{equip})~~

~~Equipment efficiency factor accounts for interactions between the duct system and the operation of the heating or cooling equipment. If the duct size and layout are designed and installed according to ACCA manual D and if the fan flow measurement meets the design specifications, the efficiency factor for F_{equip} is 1. Otherwise F_{equip} shall be 0.925. For heating, F_{equip} is 1.~~

~~4.5.2 Thermal Regain (F_{regain})~~

~~The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The default thermal regain factors are provided in Table 4.4.~~

~~Table 4.4 Thermal Regain Factors~~	
~~Supply Duct Location~~	~~Thermal Regain Factor [F_{regain}]~~
~~Attic~~	~~0.10~~
~~Crawlspace~~	~~0.12~~
~~Basement~~	~~0.30~~
~~Other~~	~~0.10~~

~~4.5.3 Recovery Factor (F_{recov})~~

~~The recovery factor, F_{recov}, is calculated based on the thermal regain factor, F_{regain}, and the duct losses without return leakage.~~

$$\cancel{F_{recov} = 1 + F_{regain}\left(\frac{1 - a_sB_s + a_sB_s(1 - B_r)\frac{\Delta T_r}{\Delta T_e} + a_s(1 - B_s)\frac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right)} \quad \cancel{(4.16)}$$

~~4.5.4 Seasonal Distribution System Efficiency~~

~~The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness from section 4.4.2, the equipment efficiency factor from section 4.5.1 and the thermal recovery factor from Section 4.5.3. Note that $DE_{seasonal}$, F_{equip}, F_{recov} must be calculated separately for cooling and heating conditions. Distribution system efficiency shall be determined using the following equation:~~

$$\cancel{\eta_{dist,seasonal} = 0.98 \; DE_{seasonal} \; F_{equip} \; F_{recov}} \quad \cancel{(4.17)}$$

~~where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass.~~

ACM RG-2005

Appendix RG – Water Heating Calculation Method

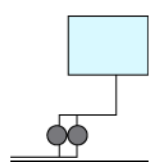
RG1. Purpose and Scope

ACM RG documents the methods and assumptions used for calculating the hourly energy use for residential water heating systems for both the proposed design and the standard design. The hourly fuel and electricity energy use for water heating will be combined with hourly space heating and cooling energy use to come up with the hourly total fuel and electricity energy use to be factored by the hourly TDV energy multiplier. The calculation procedure applies to low-rise single family, low-rise multi-family, and high-rise residential.

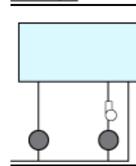
When buildings have multiple water heaters, the hourly total water heating energy use is the hourly water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

The following diagrams illustrate some of the cases that are recognized by ACM.

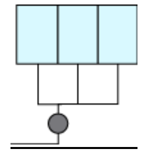
1 One distribution system with two water heaters serving a single dwelling unit.



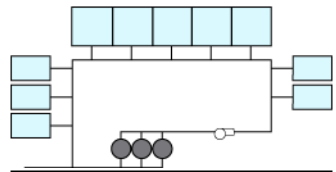
2 Two distribution systems, each with a single water heater serving a single dwelling unit.



3 One distribution system with one water heater serving multiple dwelling units.



4 Single distribution system with multiple water heaters serving multiple units.



The following rules apply to the calculation of water heating system energy use:

- One water heater type per system, e.g. no mix of gas and electric water heaters in the same system
- One solar or woodstove credit (but not both) per system

RG2. Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.

i Used to describe an individual dwelling unit. For instance CFAi would be the conditioned floor area of the i^{th} dwelling unit. "N" is the total number of dwelling units.

j Used to refer to the number of water heaters in a system. "M" is the total number of water heaters.

k Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.

RG3 Hourly Adjusted Recovery Load

The hourly adjusted recovery load (HARL) can be calculated by Equation RG-1 through Equation RG-7.

Equation RG-1 $$HARL_k = HSEU_k \times DLM_k \times SSM_k + HRDL_k$$

This equation calculates the hourly recovery load on the water heater. The hourly adjusted recovery load (HARL) is the heat content of the water delivered at the fixture (HSEU) times the distribution loss multiplier (DLM) times the solar saving multiplier (SSM) plus the hourly recirculation losses between dwelling units (HRDL), which only occurs for multi-family central water heating systems and is zero for single family dwellings. The DLM will generally be greater than one, which means that heat is wasted as water flows from the water heater to the fixture. The DLM_k is constant for all hours with water heating end use.

Equation RG-2 $$HSEU_k = 8.345 \times GPH_k \times \Delta T$$

This equation calculates the hourly standard end use (HSEU) for each hour at all fixtures. The heat content of the water delivered at the fixture is the draw volume in gallons (GPH) times the temperature rise ΔT (difference between the cold water inlet temperature and the hot water supply temperature) times the heat required to elevate a gallon of water 1ºF (the 8.345 constant). GPH are calculated in a manner consistent with the

Standard Recovery Load values in the current water heating methodology (see RG3.2.1 Pipe Insulation Eligibility Requirements).

Equation RG-3 $$\Delta T = T_s - T_{inlet}$$

Temperature difference (ºF) between cold water inlet temperature T_{inlet} and the hot water supply temperature T_s.

Equation RG-4 $$DLM_k = 1 + (SDLM_k - 1) \times DSM_k$$

This is the equation for the distribution loss multiplier. It combines two terms: the standard distribution loss multiplier (SDLM), which depends on the size of the dwelling unit and the number of stories, and the distribution system multiplier (DSM) listed in Table RG-2. For point-of-use (POU) distribution systems located in close proximity to all hot water fixtures (see RG3.2.1 Pipe Insulation Eligibility Requirements), DLM is equal to one, e.g. there are no distribution losses.

Equation RG-5 $$SDLM_k = 1.074 + 0.00010 \times CFA_k$$

This equation gives the standard distribution loss multiplier (SDLM) for one story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). Multi-family SDLM's will be calculated based on the one story equation and the average CFA for all units. CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RG-6 $$SDLM_k = 0.993 + 0.00008 \times CFA_k$$

This equation gives the standard distribution loss multiplier (SDLM) for two and three story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RG-7 $$SSM_k = 1 - SSF_k \times A$$

This equation gives the solar savings multiplier (unitless) for the k^{th} water heating system. Equation RG-11 and Equation RG-12 provide more detail.

where

$HARL_k$ = Hourly adjusted recovery load (Btu).

$HSEU_k$ = Hourly standard end use (Btu). This is the amount of heat delivered at the hot water fixtures relative to the cold water inlet temperature.

$HRDL_k$ = Hourly recirculation distribution loss (Btu) is the hot water energy loss in multi-family central water heating recirculation systems (See RG3.5 Hourly Recirculation Distribution Loss for

Central Water Heating Systems).HRDL is zero for all single family water heating systems and for multi-family systems with individual water heaters.

DLM_k = Distribution loss multiplier (unitless).

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system provided in RG3.1 Hourly Hot Water Consumption (GPH).

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in RG3.3 Cold Water Inlet Temperature.

$SDLM_k$ = Standard distribution loss multiplier (unitless). This is calculated using Equation RG-5 for single story dwelling units and from Equation RG-6 for dwelling units with two or more stories. All multi-family projects utilize Equation RG-5 and the average dwelling unit CFA.

DSM_k = Distribution system multiplier (unitless) provided in RG3.2 Distribution System Multiplier (DSM) within the Dwelling Unit.

CFA_k = Conditioned floor area (ft^2) capped at 2500 ft^2 for all single and multi-family units.

When a water heating system has more than one water heater, the total system load is assumed to be shared equally by each water heater. The HARL for the j^{th} water heater is then shown in the following equation.

Equation RG-8
$$HARL_j = \frac{HARL_k}{NmbrWH_k}$$

where

$NmbrWH_k$ = The number of water heaters in the k^{th} system.

RG3.1 Hourly Hot Water Consumption (GPH)

The average daily hot water consumption GPD for a dwelling unit is equal to 21.5 gallons/day plus an additional 14 gallons per day for each 1000 ft² of conditioned floor area. Consumption is about 31.3 gallons/day for a 700 ft² apartment and 56.5 gallons/day for a 2500 ft² dwelling unit. The equation for daily hot water consumption can be expressed as follows[1]:

Equation RG-9
$$GPD_I = 21.5 + 0.014 \times CFA_I$$

where

GPD_i = Average daily hot water consumption (gallons) of the i^{th} dwelling unit.

CFA_i = Conditioned floor area (ft²) of the i^{th} dwelling unit. When actual conditioned floor area is greater than 2500 ft², 2500 should be used in the above equation.

The hourly water consumption GPH of the k^{th} system is calculated using the average daily hot water consumption and the hourly water consumption schedule for all dwelling units served by the system.

[1] COMMENTARY: This equation is derived from the 2001 Residential ACM Approval Manual SRL equation assuming a deltaT of 75ºF (supply temperature of 135ºF and inlet temperature of 60ºF) and 22% distribution losses (0.82 adjustment factor). Hot water use predicted in this equation includes the demand for clothes washers. If multi-family dwellings have a separate laundry facility with a separate water heating system, then 17% of the hot water use predicted by Equation 4.2 shall be assigned to the laundry's hot water system and the remaining 83% should be assigned to the dwelling units. The hourly schedule in Table RG-1 is used for both the laundry and the dwelling units.

Equation RG-10 $$GPH_k = \left(\sum_i GPD_i\right) \times SCH_m$$

where

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

SCH_m = Fractional daily load for hour "m" from Table RG-1.

m = Hour of the day.

There are significant variations between hot water usage on weekdays and weekends, and separate schedules are used. The hourly schedules shown in Table RG-1 shall be used for calculating the hourly hot water consumption. These data are used for dwelling units of all types.

Table RG-1 Hourly Water Heating Schedules

Hour	**Weekday**	**Weekend**
1	0.014	0.018
2	0.008	0.010
3	0.009	0.009
4	0.011	0.008
5	0.020	0.015
6	0.044	0.023
7	0.089	0.026
8	0.107	0.047
9	0.089	0.077
10	0.066	0.083
11	0.052	0.074
12	0.038	0.061
13	0.036	0.051
14	0.033	0.043
15	0.032	0.039
16	0.026	0.039
17	0.042	0.052
18	0.048	0.058
19	0.052	0.056
20	0.047	0.052
21	0.042	0.047
22	0.039	0.044
23	0.036	0.040
24	0.022	0.028
Sum	1.000	1.000

RG3.2 Distribution System Multiplier (DSM) within the Dwelling Unit

The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems within the dwelling unit. A value of one is used for standard distribution systems defined as a "main and branch" piping system with all lines leading from the water heater to the kitchen fixtures insulated to a nominal R-4. Values for alternative distribution systems are given in Table RG-2.

Table RG-2 Distribution System Multipliers within a Dwelling Unit with One or More Water Heaters

Distribution System Measure	Code	DSM
Pipe Insulation (all lines)	PIA	0.92
Point of Use	POU	0.00
Pipe Insulation (kitchen lines) – Standard Case	PIK	1.00
Parallel Piping	PP	1.09
Recirculation (no control)	RNC	4.81
Recirculation + timer control	RTm	3.22
Recirculation + temperature control	RTmp	3.97
Recirculation + timer/temperature	RTmTmp	2.65
Recirculation + demand control	RDmd	1.39

RG3.2.1 Pipe Insulation Eligibility Requirements

Mandatory Measures for pipe insulation on the first five feet of hot and cold water piping from storage gas water heaters and for pipe insulation for non-recirculation systems on all piping from the water heater to the kitchen fixtures (kitchen sink and dishwasher) as specified in Section 150 (j) of Title 24, Part 6.

Pipe insulation credit available if all remaining hot water lines are insulated. Insulation shall meet mandatory minimums in Section 150 (j).

Overhead Plumbing for Non-Recirculation Systems. All plumbing located in attics with a continuous minimum of 4 in. of blown insulation coverage on top of the piping will be allowed to claim the “all lines” pipe insulation credit, provided that:

1. Piping from the water heater to the attic, and
2. Piping in floor cavities or other building cavities are insulated to the minimum required for pipe insulation credit.

RG3.2.2 Point of Use Water (POU) Water Heaters Eligibility Requirements

Current requirements apply. All hot water fixtures in the dwelling unit, with the exception of the clothes washer, must be located within 8’ (plan view) of a point of use water heater. To meet this requirement, some houses will require multiple POU units.

RG3.2.3 Recirculation Systems Eligibility Requirements

All recirculation systems must have minimum nominal R-4 pipe insulation on all supply and return recirculation piping. Recirculation systems may not take an additional credit for pipe insulation.

The recirculation loop must be laid out to be within 8 feet (plan view) of all hot water fixtures in the house (with the exception of the clothes washer).

Approved recirculation controls include “no control”, timer control, time/temperature control, and demand control. Time/temperature control must have an operational timer initially set to operate the pump no more than 16 hours per day. Temperature control must have a temperature sensor with a minimum 20°F deadband installed on the return line.

Demand recirculation systems shall have a pump (maximum 1/8 hp), control system, and a timer or temperature sensor to turn off the pump in a period of less than 2 minutes from pump activation. Acceptable control systems include push buttons, occupancy sensors, or a flow switch at the water heater for pump initiation. At a minimum, push buttons and occupancy sensors must be located in the kitchen and in the master bathroom.

RG3.2.4 Parallel Piping Eligibility Requirements

Each hot water fixture is individually served by a line, no larger than ½ in., originating from a central manifold located no more than 8 feet from the water heater. Fixtures, such as adjacent bathroom sinks, may be “doubled up” if fixture unit calculation in Table 6-5 of the 2000 Uniform Plumbing Code allow.

Acceptable piping materials include copper and cross-linked polyethylene (PEX), depending upon local jurisdictions.

3/8 in. lines are acceptable, pending local code approval, provided minimum required pressures listed in the 2000 UPC (Section 608.1) can be maintained.

Parallel piping to the kitchen fixtures (dishwasher and sink(s)) must be insulated to comply with the mandatory measure for kitchen line pipe insulation.

RG3.3 Cold Water Inlet Temperature

The water inlet temperature varies monthly by climate zone and is equal to the assumed ground temperature as shown in Table RG-3.

Table RG-3 Monthly Ground Temperature (ºF)

Climate Zone	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7

RG3.4 Solar Savings Multiplier

Solar water heating systems are rated using information from the Solar Rating and Certification Corporation (SRCC). Two types of ratings are possible, those using SRCC OG-300 and those using SRRC OG-100.

RG3.4.1 Determining Solar Savings Multiplier for SRCC OG-300 Rated Systems

For solar water heating systems rated using SRCC OG-300, the solar savings multiplier SSM_k is calculated as follows:

Equation RG-11

$$SSM_k = \left(\frac{\left(\frac{EF_{test,k} \times Q_{deltest}}{SEF_{rated,k}}\right) x \left(\frac{GPD_k}{64.3}\right) \times \left(\frac{T_s - T_{inlet}}{77}\right) + 3500 \times SYS_{type,k} \times (1 - EF_{test,k})}{Q_{deltest}} \right) \times \left(\frac{1500}{\sum_{hr=1}^{hr=24} I_{hor,hr}} \right) \times A$$

where

$EF_{test,k}$ = Energy Factor used in SRCC OG-300 rating method for auxiliary water heater type used for rating. Two values are possible, 0.90 for a rating with an electric auxiliary water heater and 0.60 for a rating with a gas auxiliary water heater.

$Q_{deltest}$ = The standard OG-300 energy in the hot water delivered, 41,045 Btu/day.

$SEF_{rated,k}$ = The SEF rating as described in SRCC OG-300[2] and the Summary OG-300 directory[3] for the k^{th} system.

3500 = Average parasitic loss for a Forced Circulation system (Btu/day).

$SYS_{type,k}$ = The OG-300 system type. There are four system types rated in OG-300. Force Circulation, Integral Collector Storage, Thermosyphon, and Self-Pumping. For Forced Circulation type systems this value is set to one. For all others, it is set to zero.

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

64.3 = The standard OG-300 water draw of 64.3 gallons per day.

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in Table RG-3.

77 = Difference between Ts and T_{inlet} used in OG-300 test (ºF).

1500 = OG-300 test daily solar insolation (Btu/hr-ft^2).

$I_{hor,hr}$ = Hourly Horizontal solar insolation from weather data for each climate zone (Btu/hr-ft^2).

Hr = Hour of the day from 1 through 24.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

Eligibility Criteria

In order to use this method, the system must satisfy the applicable eligibility criteria, including:

- The collectors must face within 35 degrees of south and be tilted at a slope of at least 3:12.
- The system must be installed in the exact configuration for which it was rated, e.g. the system must have the same collectors, pumps, controls, storage tank and auxiliary system fuel type as the rated condition.
- The system must be installed according to manufacturer's instructions.
- The collectors shall be located in a position that is not shaded by adjacent buildings or trees between 9:00 AM and 3:00 PM (solar time) on December 21.

RG3.4.1 Determining Solar Savings Multiplier for SRCC OG-100 Rated Equipment

Calculating solar hot water system energy contributions requires that the system be modeled using F-chart. Version 4.0 and all later versions can be used to calculate the percent of water heating energy delivered by the solar system. The data listed in Table RG-4 should be followed as inputs and guidelines for correctly modeling solar hot water systems. If the collector type is not flat plate then the user should refer to the F-chart user manual.

[2] SRCC Document OG-300, Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems, May 2002, Solar Rating and Certification Corporation

[3] Summary of SRCC Certified Solar Collector and Water Heating System Ratings, March 2003, Solar Rating and Certification Corporation

Table RG-4 Prototype Solar System

F-Chart Parameter	***Value***
Collector - Number of	Enter the number of collectors in the system
Collector Area	Enter square feet of the collector listed in the SRCC directory
Collector (test slope) or FR*UL from SRCC data	Enter the value listed in the SRCC directory (I.E. -.272)
Collector (test intercept) or FR*TAU*ALPHA from SRCC data	Enter the value listed in the SRCC directory (I.E. .5007)
Collector Slope	Use degrees (I.E. 23)
Collector Orientation	Enter a value between 0 and 180, with south being 0. F-chart does not distinguish between East and West.
Collector Incident angle modifier calculation	Should always be set to glazing
Collector Flow Rate/Area	Unless calculated a default of 11 lb/hr-ft2 should be used. This value is calculated by dividing the flow rate of the system by the collector area
Collector Fluid Specific Heat	Should be set to 1.00 for water, 0.8 for glycol and 0.23 for air. Units in Btu/lb-F
Collector Modify Test Values	Should always be set to “no”
System location	Select the city that represents the climate zone the permitted building is located in[J17].
System water volume/collector ratio	Calculated by dividing the volume of the storage tanks and collectors by the collector area. Does not include piping volume
System auxiliary fuel type	The default [J18]is gas – this input does not change results
System Efficiency of (auxiliary) fuel usage	The default is 1 – this input does not change results
System Daily hot water usage	Value must be calculated using Equation RG-9
System water set temperature	Value must be set to 135
System environmental temperature	Value must be the January value from table RG-3
System UA of auxiliary storage tank	Calculated using the value determined with Equation RG-33 times 1/R value of the insulation.
System pipe heat loss	Value may be assumed to be 0
System collector-store heat exchanger	Enter Yes or No
Tank-side flow-rate/area	Entered in lbs/hr-ft2 is the mass flow rate of water from the storage tank through the collector-storage heat exchanger divided by the total collector area. This value should be set to a value larger than the collector flow rate/area in the collector parameters for an internal heat exchanger)
Heat exchanger effectiveness	Is the ratio of the actual to maximum possible heat transfer rates for the heat exchanger located between the collector and storage unit.

F-chart will generate a Solar Fraction (SF). This value is an annual fraction of the total hot water demand met by the solar system. To adjust the SF to daily loads use Equation RG-12.

Equation RG-12
$$SSM_k = ((1 - SF_k) \times A)$$

where

SF = Solar Factor (SF) derived from F-chart.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

RG3.5 Hourly Recirculation Distribution Loss for Central Water Heating Systems

The distribution losses accounted for in the distribution system multiplier DSM are within each individual dwelling unit. Additional distribution losses occur in most multi-family dwelling units related to recirculation systems between dwelling units. These losses include losses from piping that is or could be part of a recirculation loop and branch piping to individual residential units. These losses are divided into losses to the outside air, the ground and the conditioned or semi-conditioned air within the building envelope.

Outside air includes crawl spaces, unconditioned garages, unconditioned equipment rooms, as well as actual outside air. Solar radiation gains are not included in the calculation because the impact of radiation gains is relatively minimal compared to other effects. Additionally, the differences in solar gains for the various conditions (e.g., extra insulation vs. minimum insulation) are relatively even less significant.

The ground condition includes any portion of the distribution piping that is underground, including that in or under a slab. Insulation in contact with the ground must meet all the requirements of Section 150 (j), Part 6, of Title 24.

The losses to conditioned or semi-conditioned air include losses from any distribution system piping that is in an attic space, within walls (interior, exterior or between conditioned and unconditioned spaces), within chases on the interior of the building, or within horizontal spaces between or above conditioned spaces. It does not include the pipes within the residence. The distribution piping stops at the point where it first meets the boundaries of the apartment.

These losses are added to the load accounted for in the hourly adjusted recovery load HARL, according to Equation RG-1 and calculated in the following equation.

Equation RG-13 $$HRDL_k = NL_{OA} \times UA_{OA} \times (T_s - T_{OA}) + NL_{UG} \times UA_{UG} \times (T_s - T_G) + NL_P \times UA_P$$

where

$HRDL_k$ = Hourly recirculation distribution loss (Million Btu).

T_s = Hot water supply temperature of 135°F.

T_{OA} = Hourly dry-bulb temperature of outside air (°F).

T_G = Hourly ground temperature (°F) assumed constant for each month.

NL_{OA} = Normalized load coefficient for outside air term.

NL_{UG} = Normalized load coefficient for underground term.

NL_P = Normalized load coefficient for conditioned or semi-conditioned term.

UA_{OA} = Heat loss rate of circulation pipe exposed to outside air (Btu/hr-°F).

UA_{UG} = Heat loss rate of circulation pipe buried under ground (Btu/hr-°F).

UA_P = Heat loss rate of circulation pipe in conditioned or semi-conditioned space (Btu/hr-°F).

The terms UA_{OA}, UA_{UG}, and UA_P represent the conductive area and heat loss rate for the three pipe locations. In each case the UA is a function of the pipe length, pipe diameter and pipe insulation. The program user will need to specify pipe length in each of the three locations, and specify the insulation as being either minimum (as specified in Section 150 (j), Part 6, of Title 24), or extra. Length and corresponding insulation R-value takeoffs are required for piping in each of the three locations (outdoors, underground, and conditioned or semi-conditioned space). Pipe heat loss rates (UA_{OA}, UA_{UG}, and UA_p) are then calculated for use in Equation RG-13.

The normalized load coefficients, NL_{OA}, NL_{UG}, and NL_P, are climate zone specific multipliers for the pipe losses to the outside air, ground and conditioned or semi-conditioned space, respectively. They are calculated according to the following equations:

Equation RG-14

$$NL_{OA} = \frac{C_{OA1} \times \exp\left(\frac{C_{OA2} \times UA_{OA}}{GPD_k}\right)}{WHDH_{OA}}$$

Equation RG-15

$$NL_{UG} = \frac{C_{UG1} \times \exp\left(\frac{C_{UG2} \times UA_{UG}}{GPD_k}\right)}{WHDH_{UG}}$$

Equation RG-16

$$NL_{P} = \frac{C_{P1} \times \exp\left(\frac{C_{P2} \times UA_{P}}{GPD_k}\right)}{8760}$$

where

GPD_k = The hot water consumption per day for the k^{th} system. It is the sum of hot water consumption per day for all dwelling units served by the k^{th} system.

$WHDH_{OA}$ = Water heating degree hours based on outside air temperature (hr-°F).

$WHDH_{UG}$ = Water heating degree hours based on ground temperature (hr-°F).

C_{OA1}, C_{OA2} = Coefficients for outside air pipe loss term.

C_{UG1}, C_{UG2} = Coefficients for underground pipe loss term.

C_{P1}, C_{P2} = coefficients for conditioned or semi-conditioned space pipe loss term.

Coefficients of C_{OA}, C_{UG}, and C_P vary by climate zones and control schemes of the circulation system. Table RG-5 lists values of these coefficients.

Table RG-5 Coefficients of C_{OA}, C_{UG} and C_P

Climate Zone	No Controls						Timer Controls					
	COA1	COA2	CUG1	CUG2	CP1	CP2	COA1	COA2	CUG1	CUG2	CP1	CP2
1	0.8933	-0.694	0.8922	-1.346	0.6259	-1.673	0.8658	-2.336	0.793	-2.062	0.6344	-4.475
2	0.854	-0.71	0.8524	-1.348	0.6433	-1.383	0.8269	-2.456	0.7572	-2.056	0.6529	-4.138
3	0.8524	-0.709	0.851	-1.355	0.6826	-1.464	0.8252	-2.37	0.7553	-2.049	0.6927	-4.438
4	0.8349	-0.688	0.8345	-1.343	0.6502	-0.706	0.8096	-2.433	0.7427	-2.071	0.667	-3.759
5	0.8494	-0.706	0.8476	-1.341	0.6873	-1.076	0.8218	-2.409	0.7536	-2.061	0.6922	-3.979
6	0.8095	-0.704	0.808	-1.341	0.7356	-1.697	0.7836	-2.367	0.718	-2.059	0.7341	-4.512
7	0.796	-0.673	0.7964	-1.349	0.735	-1.581	0.7734	-2.395	0.7082	-2.064	0.7416	-4.579
8	0.7941	-0.704	0.7925	-1.341	0.7321	-1.471	0.7683	-2.414	0.7049	-2.064	0.7333	-4.318
9	0.7853	-0.707	0.7843	-1.352	0.7208	-1.212	0.7599	-2.447	0.6971	-2.064	0.7248	-4.141
10	0.7854	-0.714	0.7843	-1.352	0.7193	-1.273	0.7595	-2.5	0.6971	-2.067	0.7188	-4.041
11	0.8137	-0.69	0.8139	-1.35	0.6149	-1.22	0.788	-2.443	0.7228	-2.051	0.6315	-4.306
12	0.8283	-0.685	0.8286	-1.349	0.6001	-0.323	0.8029	-2.451	0.7367	-2.061	0.621	-3.493
13	0.7818	-0.705	0.7813	-1.352	0.6699	-1.541	0.7564	-2.465	0.6937	-2.052	0.6752	-4.305
14	0.8094	-0.706	0.809	-1.351	0.6424	-0.866	0.784	-2.49	0.7187	-2.059	0.6515	-3.588
15	0.6759	-0.692	0.6764	-1.348	0.7514	-1.383	0.6535	-2.552	0.601	-2.061	0.7493	-4.182
16	0.9297	-0.701	0.929	-1.352	0.5231	-1.519	0.9007	-2.401	0.825	-2.053	0.5437	-4.423

Table RG-5 provides coefficients for recirculation systems where the pumps are always on and coefficients for recirculation systems that are shut off during hours 1 through 5, and hours 23 and 24 (from 10p.m. to 5a.m.). Except for systems serving only a very small number of dwelling units, there is no set of coefficients provided for the case where the circulation system does not rely on a recirculation pump. Such a system would be unlikely to supply hot water within parameters acceptable to tenants. It can be assumed that any distribution systems for supplying hot water from a central boiler or water heater require a recirculation pump and one would be supplied retroactively if not initially. For central hot water systems serving six or fewer dwelling units which have (1) less than 25' of distribution piping outdoors; (2) zero distribution piping underground; (3) no recirculation pump; and (4) insulation on distribution piping that meets the requirements of Section 150 (j) of Title 24, Part 6, the distribution system in the Standard Design and Proposed design will both assume a pump with timer controls.

$WHDH_{OA}$ is the sum of the differences between the temperature of the supply hot water (135˚F) and the hourly outdoor temperature for all 8760 hours of the year. This term varies by climate zone. The values for this term are listed in Table RG-6 below. The equation uses the hourly outdoor temperatures from the weather files incorporated in the CEC approved programs.

$WHDH_{UG}$ is the sum of the differences between the supply hot water temperature (135˚F) and the hourly ground temperature for all 8760 hours of the year. This term varies by climate zone. The appropriate values for this term are listed in Table RG-6 below. The equation uses the ground temperatures from the weather files incorporated in the CEC approved programs, which are assumed to be stable on a monthly basis.

Table RG-6 Water Heating Degree Hours for Outside Air and Underground

Climate Zone	$WHDH_{OA}$ (hr-°F)	$WHDH_{UG}$ (hr-°F)
1	712810	710306
2	680634	678425
3	679350	677026
4	666823	664459
5	677373	674935
6	645603	643236
7	636342	633811
8	633244	630782
9	626251	623822
10	625938	623741
11	649661	647770
12	661719	659676
13	623482	621526
14	645367	643517
15	539736	537782
16	741372	739378

UA terms are calculated using inputs provided by the user and base assumptions about the pipe diameter: The user inputs are:

1. Pipe length in each of the three locations.
2. Insulation R value of the pipe in each location.
3. Number of stories above grade.
4. Number of apartment units.

The total length of the circulation pipe is calculated, along with the fraction in each location (PF_{OA}, PF_{UG} and PF_P). The square feet of surface area is calculated according to the following equation:

Equation RG-17

$$SF_{total} = LF_{total} \times Dia \times \pi$$

where

SF_{Total} = The total surface area of the circulation piping, square feet.

LF_{Total} = The total lineal feet of all circulation piping, feet.Dia = Average calculated (Equation RG-18) diameter of pipe in circulation piping, feet.

π = Pythagorean constant (ratio of perimeter to diameter), 3.1416

The average diameter of hot water piping, Dia, is calculated by the following equation[4]:

Equation RG-18

$$Dia = 0.045 \times \left(\frac{LF_{Total}}{\Delta P}\right)^{0.21} \times (AptGPM)^{0.37} \times \frac{(NumApts)^{0.37}}{1.37}$$

[4] Based on an integration of Bernoulli's equation described in the PG&E CASE report. Note that this equation provides a reasonable approximation of the area of pipe while avoiding the enforcement problems that would exist by the potentially more accurate approach of asking the user to input the length of pipe of each diameter in each location. Such an approach would rely on data that could not be easily field-verified.

The terms of the above equation are described below. The total system pressure drop, ΔP, given in psf is calculated in Equation RG-19.

Equation RG-19 $$\Delta P = \left[P_{meter} - 4.3 \times (NumStories - 1) - 15\right] \times 144$$

where

P_{meter} = Water system supply pressure, (60 psig by assumption).

NumStories = Number of stories above grade, (but enter “4” if more than 4 stories).

Equation RG-20 $$AptGPM = \frac{1.765 \times (12 \times NumApts)^{0.687}}{NumApts}$$

NumApts = Number of apartments in the building served by the hot water system, apts

The UA for each of the three locations is derived as a function of the fraction of the total pipe in that location times a factor that represents the conductivity of the standard (minimum) insulation or the “extra” insulation condition. The following two equations provide the alternate equations for the two insulation cases. The factors do not vary by location so the equations for the other two locations are of exactly the same form, varying only by the fraction of pipe in that location.

The benefits of additional insulation shall be calculated as required in Section 150 (j) of Title 24. The insulation value of the ground and of protective coverings may not be used for achieving the minimum insulation values required by Section 150 (j). To qualify as extra insulation, the insulation must be at least 1/2" thicker than the insulation required by Section 150 (j).

Equation RG-21 For extra insulation for the standard design: $$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick + 0.5}{Radius}\right)} \right)$$

Equation RG-22 For minimum insulation: $$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick}{Radius}\right)} \right)$$

where

i = Subscript indicating pipe location OA = outside, UG = underground, P = conditioned or semi-conditioned space

PF_i = Pipe fraction in i^{th} location, no units

k = Insulation conductivity, (assumed 0.25 Btu inch/h·sf·°F)

Radius = Average pipe radius in inches, (Radius = Dia x 12 / 2), inches

Thick = Base case insulation thickness, Thick = 1 if average pipe radius is less than or equal to 2";Thick = 1.5 if radius is greater than 2", inches

RG3 Energy Use of Individual Water Heaters

Once the hourly adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below.

RG4.1 Small[5] Gas, Oil, or Electric Storage and Heat Pump Water Heaters

The hourly energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

Equation RG-23

$$WHEU_j = \left[\frac{HARL_j \times HPAF_j}{LDEF_j}\right] WSAF_j$$

where

$WHEU_j$ = Hourly energy use of the water heater (Btu for fuel or kWh for electric), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load (Btu).

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

The energy consumption of one or more independent hot water storage tanks that are not rated as water heaters is calculated by substituting $xHARL_j$ for $HARL_j$ where $xHARL_j$ is defined in Section __.

Table RG-7 Heat Pump Adjustment Factors

Climate Zone	Heat Pump Adjustment Factor	Climate Zone	Heat Pump Adjustment Factor
1	1.040	9	0.920
2	0.990	10	0.920
3	0.990	11	0.920
4	1.070	12	1.070
5	1.070	13	0.920
6	0.920	14	1.040
7	0.920	15	0.920
8	0.920	16	1.500

$LDEF_j$ = The hourly load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the standard EF for different load conditions.

Equation RG-24

$$LDEF_j = e \times \left(\ln\left(\frac{HARL_j \times 24}{1000}\right)\left(a \times EF_j + b\right) + \left(c \times EF_j + d\right)\right)$$

[5] "Small water heater" means a water heater that is a gas storage water heater with an input of 75,000 Btu per hour or less, an oil storage water heater with an input of 105,000 Btu per hour or less, an electric storage water heater with an input of 12 kW or less, a gas instantaneous water heater with an input of 200,000 Btu per hour or less, an oil instantaneous water heater with an input of 210,000 Btu 1602 per hour or less, an electric instantaneous water heater with an input of 12 kW or less, or a heat pump water heater rated at 24 amps or less.

where

a,b,c,d,e = Coefficients from the table below based on the water heater type.

Table RG-8 LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
a	-0.098311	-0.91263	0.44189
b	0.240182	0.94278	-0.28361
c	1.356491	4.31687	-0.71673
d	-0.872446	-3.42732	1.13480
e	0.946	0.976	0.947

Note: EF for storage gas water heaters under 20 gallons must be assumed to be 0.58 unless the manufacturer has voluntarily reported an actual EF to the California Energy Commission. As of April 2003, manufacturers of this equipment are no longer required to do so.

EFj = Energy factor of the water heater (unitless). This is based on the DOE test procedure.

WSAFj = Wood stove boiler adjustment factor for the j^{th} water heating system. This is given in Section RG4.5 Wood Stove Adjustment Factors. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG4.2 Small Gas or Oil Instantaneous[6]

The hourly energy use for instantaneous gas or oil water heaters is given by the following equations.

Equation RG-25 $$WHEU_j = \left(\frac{HARL_j}{EF_j} + PILOT_j\right) \times WSAF_j$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers literature or from the CEC Appliance Database.

$PILOT_j$ = Energy consumption of the pilot light (Btu/h). Default if no information provided in manufacturer's literature or CEC Appliance Database is 500 Btu/hr.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG4.3 Small Electric Instantaneous

The hourly energy use for instantaneous electric water heaters is given by the following equation.

Equation RG-26 $$WHEU_{j,elec} = \frac{HARL_j \times WSAF_j}{3413 \times EF_j}$$

where

$WHEU_{j,\ elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

[6] "Instantaneous water heater" means a water heater that has an input rating of at least 4,000 Btu per hour per gallon of stored water.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from DOE test procedure (unitless).

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG4.4 Large[7] Gas or Oil Storage. Large Instantaneous, Indirect Gas and Hot Water Supply Boilers[8].

Energy use for large storage gas and indirect gas water heaters is given by the following equations. Note: large storage gas water heaters are defined as any gas storage water heater with a minimum input rate of 75,000 Btu/h.

Equation RG-27

$$WHEU_j = \left[\frac{HARL_j + HJL_j}{EFF_j \times EAF_j} + PILOT_j\right] \times WSAF_j$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute $xHARL_j$ from Section RG4.8 Independent Hot Water Storage Tanks for $HARL_j$.

HJL_j = Hourly jacket loss (Btu/h) for tank rated with the water heater. For nonstorage water heaters and boilers set this term to zero. To account for independent hot water storage tanks substitute $xHARL_j$ (from Section RG4.8 Independent Hot Water Storage Tanks) for $HARL_j$ storage tanks

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

EAF_j = Efficiency adjustment factor (unitless). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.

$PILOT_j$ = Pilot light energy (Btu/h) for large instantaneous. For large instantaneous water heaters, and hot water supply boilers the default is 750 Btu/hr if no information is provided in manufacturer's literature or CEC Appliance Database. For storage type water heaters the default is zero.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG4.5 Large Electric Storage

Energy use for large storage electric water heaters is given by the following equation.

Equation RG-28

$$WHEU_{j,elec} = \left[\frac{HARL_j + HJL_j}{0.85 \times 3.413}\right] \times WSAF_J$$

where

7 "Large water heater" means a water heater that is not a small water heater.

8 "Hot water supply boiler" means an appliance for supplying hot water for purposes other than space heating or pool heating.

$WHEU_{j,\,elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

HJL_j = Hourly jacket loss (Btu/h) for the tank rated with the heater.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG4.5 Wood Stove Adjustment Factors

This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether the wood stove boiler has a recirculation pump. The inclusion of this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.

Table RG-9 Wood Stove Adjustment Factors

Climate Zone	Wood Stoves with Pumps	Wood Stoves without Pumps
1	0.775	0.750
2	0.775	0.750
3	0.775	0.750
4	0.865	0.850
5	0.865	0.850
6	0.910	0.900
7	0.910	0.900
8	0.955	0.950
9	0.910	0.900
10	0.955	0.950
11	0.910	0.900
12	0.865	0.850
13	0.910	0.900
14	0.910	0.900
15	1.000	1.000
16	0.730	0.700

RG4.6 Jacket Loss

The hourly jacket loss for large storage gas and indirect gas water heaters is calculated as

Equation RG-29
$$HJL_J = \frac{TSA_j \times \Delta TS}{RTI_j + REI_j} + FTL_j$$

where

TSA_j = Tank surface area (ft^2).

FTL_j = Fitting losses[9]. This is a constant 61.4 Btu/h.

REI_j = R-value of exterior insulating wrap.

9 See Davis Energy Group report, Section III, Page A-8.

RTI_j = Calculated R-value of insulation internal to water heater.

For water heaters with standby loss rated in percent heat content of the stored water:

Equation RG-30
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[(8.345 \times VOL_j \times SBL_j \times \Delta T) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

For water heaters with standby loss rated in Btu/hr:

Equation RG-31
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[\left(SBE_j \times \left(\frac{\Delta TS}{60}\right)\right) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

SBE_j = Standby loss expressed in Btu/hr from the CEC Appliance Database or from manufacturer's literature.

SBL_j = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the CEC Appliance Database or from manufacturer's literature.

$PILOT_j$ = Pilot light energy (Btu/h). If no information is provided in manufacturer's literature or CEC Appliance Database default to zero.

ΔTS = Temperature difference between ambient surrounding water heater and hot water supply temperature (ºF). Hot water supply temperature shall be 135ºF. For water heaters located inside conditioned space use 75ºF for the ambient temperature. For water heaters located in outside conditions use hourly dry bulb temperature ambient.

The hourly jacket loss for large storage electric heaters is calculated as:

Equation RG-32
$$HJLi = \frac{TSA \times \Delta T}{(RTIj + REIj)}$$

(same definitions as above)

RTIj = Calculated R-value of insulation internal to water heater.

REIj = R-value of exterior insulating wrap.

Where the calculated insulation R-value RTI_j is calculated by:

Equation RG33
$$RTIj = \frac{(TSAj \times \Delta TS)}{\left[(8.345 \times VOLj \times SBLj \times \Delta TS) \times EFFj\right]}$$

where

SBLj = Standby loss expressed in percent heat content loss of the stored water, from manufacturer's data.

EFFj = Efficiency, from manufacturer's data.

RG4.7 Tank Surface Area

Tank surface area (TSA) is used to calculate the hourly jacket loss (HJL) for large storage gas, indirect gas water heaters, and large storage electric water heaters. TSA is given in the following equation as a function of the tank volume.

Equation RG-34

$$TSA_j = e \times \left(f \times VOL_j^{0.33} + g\right)^2$$

where

VOL_j = Tank capacity (gallons).

e, f, g = Coefficients given in the following table.

Table RG-10 Coefficients for Calculating Tank Surface Areas

Coefficient	Storage Gas	Large Storage Gas and Indirect Gas	Storage Electric and Heat Pumps
E	0.00793	0.01130	0.01010
F	15.67	11.8	11.8
G	1.9	5.0	5.0

RG4.8 Independent Hot Water Storage Tanks

The additional loads due to independent hot water storage tanks which are not rated as water heaters is calculated by adding the sum of the jacket losses for one or more of these tanks to the Hourly Adjusted Recovery Load for the jth water heater and substituting $xHARL_j$ for $HARL_j$ in the appropriate equation above for the jth water heater:

Equation RG-35

$$xHARL_j = HARL_j + \sum_k HJL_{j,k}$$

where

$xHARL_j$ = Hourly Adjusted Recovery Load for the jth water heater plus the load due to independent hot water storage tanks serving the jth hot water heater.

$HARL_j$ = Hourly Adjusted Recovery Load for the jth water heater as defined by Equation RG-1.

$HJL_{j,k}$ = Hourly Jacket Loss of the kth independent hot water storage tank serving the jth water heater.

The hourly jacket loss, HJL is calculated per RG4.6 Jacket Loss using Equation RG-29. When the Standby Loss for the tank is not available or not listed, RTIj may be set at zero and the total tank insulation may be entered for REI, The minimum value of REI allowed by the ACM shall be a 0.68 still air film.

RG5 Electricity Use for Circulation Pumping

For single-family recirculation systems, hourly pumping energy is fixed as shown in following table.

Table RG-11 Single Family Recirculation Energy Use (kWh) by Hour of Day

Hour	Uncontrolled Recirculation	Timer Control	Temperature Control	Timer/Temp Control	Demand Recirculation
1	0.040	0	0.0061	0	0.0010
2	0.040	0	0.0061	0	0.0005
3	0.040	0	0.0061	0	0.0006
4	0.040	0	0.0061	0	0.0006
5	0.040	0	0.0061	0	0.0012
6	0.040	0	0.0061	0	0.0024
7	0.040	0.040	0.0061	0.0061	0.0045
8	0.040	0.040	0.0061	0.0061	0.0057
9	0.040	0.040	0.0061	0.0061	0.0054
10	0.040	0.040	0.0061	0.0061	0.0045
11	0.040	0.040	0.0061	0.0061	0.0037
12	0.040	0.040	0.0061	0.0061	0.0028
13	0.040	0.040	0.0061	0.0061	0.0025
14	0.040	0.040	0.0061	0.0061	0.0023
15	0.040	0.040	0.0061	0.0061	0.0021
16	0.040	0.040	0.0061	0.0061	0.0019
17	0.040	0.040	0.0061	0.0061	0.0028
18	0.040	0.040	0.0061	0.0061	0.0032
19	0.040	0.040	0.0061	0.0061	0.0033
20	0.040	0.040	0.0061	0.0061	0.0031
21	0.040	0.040	0.0061	0.0061	0.0027
22	0.040	0.040	0.0061	0.0061	0.0025
23	0.040	0	0.0061	0	0.0023
24	0.040	0	0.0061	0	0.0015
Annual Total	350	234	53	35	23

Multi-family recirculation systems may have vastly different pump sizes and is therefore calculated based on the installed pump size. The hourly electricity use for pumping (HEUP) water in the circulation loop can be calculated by the hourly pumping schedule and the power of the pump motor as in the following equation.

Equation RG-36

$$HEUP_k = \frac{0.746 \times PUMP_k \times SCH_{k,m,}}{\eta_k}$$

where

$HEUP_k$ = Hourly electricity use for the circulation pump (kWh).

$PUMP_k$ = Pump brake horsepower (bhp).

η_k = Pump motor efficiency.

$SCH_{k,m}$ = Operating schedule of the circulation pump. For 24-hour operation (no controls), the value is always 1. For timer controls, the value is 1 when pump is on and 0 otherwise. The pump is assumed off from 10 p.m. to 5 a.m. and on for the remaining hours.

~~APPENDIX G~~

~~APPENDIX G~~

~~APPLICATION PACKAGE FOR CERTIFICATION OF SOLAR~~

~~WATER HEATING ENERGY PERFORMANCE CALCULATION~~

~~METHODS FOR RESIDENTIAL BUILDINGS~~

~~California Energy Commission~~

~~1516 Ninth Street~~

~~Sacramento California 95814~~

~~June 25, 1985~~

~~Revision: June 1, 1998~~

~~TABLE OF CONTENTS~~

~~I. INTRODUCTION~~

~~On July 15, 1981 the California Energy Commission (CEC) adopted new standards for residential buildings that include a performance or energy budget approach for demonstrating compliance. The new building standards were devised to reduce energy consumption in the housing market through the use of more efficient appliances and greater utilization of conservation and solar design technologies.~~

~~These performance standards establish energy budgets for both the space conditioning and water heating elements of a proposed building. One option for demonstrating compliance requires the designer to calculate the building's estimated annual energy use using a certified energy analysis calculation method in conjunction with established weather and building operation information. Solar domestic hot water systems are an integral part of these standards and can be used to demonstrate compliance with the water heating element. For typical flat plate solar collector systems as used in active solar water heating systems, the CEC has certified F-Chart 4.0 and 4.1. For all passive type water heating systems, thermosyphon and integral collector/storage (ICS) systems, the CEC has certified a calculation procedure to calculate system total annual energy contribution (Attachment J). Passive solar water heating credits are derived from test results published by the Solar Rating and Certification Corporation (SRCC) in conjunction with climate zone specific weather data for California. Climate zone insolation data and ambient air temperature and water main temperature data are required to calculate passive solar credit. Documentation for each analysis approach can be obtained from the following sources:~~

~~F-Chart~~

~~Solar Energy Laboratory~~
~~University of Wisconsin~~
~~Madison, WI 53706~~
~~(608)263-1590~~

~~Passive Method~~

~~California Energy Commission~~
~~Residential Office~~
~~1516 Ninth Street, MS-25~~
~~Sacramento CA 95814-5512~~

~~The purpose of this certification package is: (1) to provide a procedure by which other analytical approaches can be used for solar water heating compliance purposes; and (2) to establish a method for certifying their use.~~

~~Other methods may be used in lieu of F-Chart 4.0 or 4.1 or the CEC's Passive Solar Heating Calculation Method to demonstrate compliance once they have been certified by the Commission. Section 10-109 (b)(1) of the California Code of Regulations, Energy Efficiency Standards for Residential and Non-residential Buildings, provides that certification may be given if documentation is provided demonstrating that the alternative calculation method:~~

~~A. Makes no changes in any input parameter values specified by the Commission;~~

~~B. Provides input and output documentation that facilitates the enforcement agency's review and meets the formatting and content criteria found in the appropriate ACM Manual;~~

~~C. Is supported by clear and concise instructions for using the method to demonstrate that the energy budget requirements of Part 6 , are met;~~

~~D. Is reliable and accurate relative to the appropriate public domain computer program; and~~

~~E. Establishes factors that, when applied to method's outputs, result in energy budgets for that alternative calculation method that are equivalent to those in Part 6 , when the buildings used to develop the energy budgets in Part 6 are modeled.~~

~~This certification process will be used to verify comparability of computer calculation results against results of the Commission's public domain solar water heating computer programs. An applicant for certification is required to perform three types of simulations in three different California specified climate zones. For those methods which are able to generate water heating budgets, the CEC's assumptions and calculation procedure for establishing the water heating budgets are presented in Section 4.21 of this ACM Manual. Section 4.21.4 considers credits for active and passive solar water heating systems. The completed certification application package must be sent to:~~

~~California Energy Commission~~
~~1516 Ninth Street, MS-25~~
~~Sacramento, CA 95814~~

~~Attn: RESIDENTIAL SOLAR WATER HEATING~~
~~CALCULATION METHOD CERTIFICATION~~

~~Any questions regarding the application package should be directed to the above address or by telephone (916) 654-4064.~~

~~Only complete applications for programs meeting the minimum requirements discussed in Section II will be evaluated.~~

~~A list of certified programs including a program abstract, an information form, and certified budget forms for each program will be made available and updated periodically as new programs are certified. Write the above address for a current list.~~

~~II. APPLICATION PACKAGE REQUIREMENTS~~

~~In order to ensure rapid processing of applications it is essential that each application be complete and be presented in a consistent format. Each certification package must contain the following items:~~

~~A. Application Form for certification of An Energy Analysis Computer Program (Form 1)~~

~~B. Tabulated Sensitivity Runs (Form 2)~~

~~C. Program Abstract~~

~~D. Table of Fixed Input Parameters and Explanation of Fixed Values~~

~~E. Summary of Sensitivity Analysis~~

~~F. Program User's Manual~~

~~If any one of these elements is missing, processing of the application will be postponed until the missing information is provided.~~

~~A. Application Form~~

~~Form 1: " Application Form for Certification of an Energy Analysis Computer Program" must be filled out completely. This form will be used by CEC staff to assess the completeness of the application package and to notify the applicant upon certification of the computer program. The applicant may then attach this form with local building department permit requests as verification to local jurisdictions of certification.~~

~~B. Tabulated Sensitivity Runs~~

~~Form 2: The program's calculated energy performance, based on net solar fractions (NSF) in "Sensitivity Analysis", must be tabulated for easy reference against the base case systems of F-Chart 4.1. Use of this form will ensure consistency in building department and program user interpretation of program results.~~

~~C. Program Abstract~~

~~This summary will enable building departments to quickly determine if the program is being used in the correct application. The abstract must briefly describe measures the program simulates and the method used for simulation such as hourly calculations, thermal equilibrium, degree days, etc. The description should include types of buildings, solar system types, applicable climate zones, output descriptions (hourly, daily, etc.) and any other features significant to the program.~~

~~D. Table of Fixed Input Parameters~~

~~This table shall list all input parameters necessary to run the program and provide definitions for their use. Explanations shall also be provided for any parameter which is different than those provided by the reference program F-Chart 4.1. This table will be used to distinguish program characteristics and to identify areas where unit values are not comparable.~~

~~E. Program Sensitivity Analysis~~

~~The results of each sensitivity analysis run must be provided as support for the summarized data presented in Form 2. Each summary must reference the particular computer input / output runs using a code or some other easily recognized means.~~

~~F. Program User's Manual~~

~~A program user's guide / manual must be submitted which describes how the program works and how one may use it in a particular computer service facility. The information provided to CEC must include all documentation that would be needed by a user of this method.~~

~~The manual must list all of the variables used, provide an explanation of each variable, and explain how to read the input and output data and distinguish their significance. It should also explain how to enter the data to run the program and describe the default values if there are any.~~

~~The User's Manual must also contain a separate section / chapter dealing specifically with California Title 24 requirements. This section should include a general description of the Title 24 process, a listing of all fixed parameters, description and listing of California weather data and climate zones and other water heating compliance criteria.~~

~~NOTE: In addition to the above certification package requirements, all applicants must submit a copy of the program on the appropriate software (3 2 " diskette) and must be compatible with MS-DOS formats.~~

~~III. SPECIFIC CRITERIA FOR CERTIFICATION~~

~~1.Input data shall be in a standard format as specified in Attachment A.~~

~~2.Output data shall be in a standard format as specified in Attachment B.~~

~~3.The discrepancy in each individual run shall not exceed "10% of the result of the same run for F-Chart 4.1.~~

~~a.Example: If the nth run of F-Chart 4.1 yields .63, then the nth run of an applicant program must yield .63 ".06 or 0.57 to 0.69.~~

~~4.Solar system data used for certification runs shall be the same data used from the test for solar equipment certification (SRCC, ARI).~~

~~b.Example: Collector efficiencies and flow rates specified in the SRCC and ARI Directories must be used for certification runs.~~

~~1.For program use, flow rates shall be converted from gallons per minute per square foot to pounds per hour per square foot in the following manner:~~

~~c.gal. x 60 min. x 8.33 lb. x 1 = flow rate lb.~~

~~d.min hr. gal. ft² hr. ft²~~

~~5.The average water use profile as given in Attachment C shall be used for certification purposes. No other load profile may be substituted.~~

~~IV. ALTERNATIVE MODELING PARAMETERS~~

~~Alternative modeling parameters such as storage tank stratification are allowed. They must, however, be completely defined and proven suitable as modeling parameters through calculation and empirical test documentation. Certification runs will exclude alternative modeling parameters.~~

~~V. FIXED INPUT PARAMETERS~~

~~The following is a list of fixed input parameters for modeling purposes:~~

1. ~~Water main temperatures (variable, see Table 1).~~
2. ~~Ambient air temperatures (variable, see Table 1).~~
3. ~~Minimum hot water set point (140 1F).~~

4. ~~Hot water demand: 50 gallons per day per unit for single family dwellings, 35 gallons per day per unit for multi-family dwellings.~~

5. ~~California specific weather, by climate zone (see Attachment I).~~

6. ~~*Auxiliary water heater efficiency*~~

7. ~~Incident angle modifier constant: compliance can be determined by: (a) use of the incidence angle modifier constant, determined experimentally as described in the ASHRAE Standards 96-1980 and 93-1986 collector test procedure and provided by SRCC and ARI in the collector Directory; or (b) setting this parameter to 0.00 and allowing the program to automatically calculate the incident angle modifier using Fresnel equations for the number of glass panes.~~

8. ~~Ground reflectance: 0.20 (may use up to 0.90 if documented).~~

~~Note: See Attachment E for a listing of all certification modeling parameters. Individual sensitivity parameters for computer certification are listed on FORM 2, Section VII of this Appendix.~~

~~*VI. PROGRAM REFERENCE INFORMATION*~~

~~The water heating budgets were calculated according to the methodology presented in Section 4.21 of this ACM Manual. Section 4.21.4 considers credits for active and passive solar systems.~~

~~The water heating methodology provides all assumptions used to determine the water heating budgets. It documents the method use to determine water heater recovery efficiency and standby losses, and can be used for all conventional gas and electric hot water heaters, as well as heat pump water heaters, instantaneous systems, systems requiring pumping energy and recirculated water, and solar water heating systems.~~

~~For purposes of this certification procedure, all programs for certification will be compared against the performance results of the reference F-Chart 4.1 program. However, the applicant is encouraged to thoroughly review Section 4.21 of this manual and this Attachment regarding the CEC's general water heating methodology.~~

~~Those areas which are critical to comparing performance results are:~~

~~(1)comparing the thermal performance of a solar hot water heating system using fixed system values;~~

~~(2)comparing the thermal performance of a solar water heating system using variable system values; and~~

~~(3)comparing the thermal performance of a solar water heating system under~~

~~i.different weather conditions.~~

~~A. Active Systems~~

~~All active solar water heating programs shall be compared against the results of F-Chart 4.1. The following parameters must be varied to demonstrate the program's sensitivities (this will result in 21 separate sensitivity runs):~~

- ~~Collector efficiency rates~~
- ~~Collector area~~
- ~~Hot water use (load)~~
- ~~Collector orientation~~
- ~~Weather~~

~~1. Collector Efficiency~~

~~Sensitivity runs shall be made for the following three conditions: Slope (FR-UL Product) and Y-intercept (FR-TAU-ALPHA).~~

~~Slope: .55, .70, and 1.25~~

~~Y-intercept: .75, .65, and .50~~

~~2. Collector Area~~

~~Sensitivity runs shall be made for the following two conditions:~~

~~Collector area: 48 sq. ft. and 64 sq. ft.~~

~~The storage tank shall be sized at the ratio of 1.5-2.0 gallons of water storage per square foot of collector area.~~

~~3. Hot Water Use~~

~~Sensitivity for the following three conditions:~~

~~Hot water use: 30, 50, and 80 gallons~~

~~4. Collector Orientation~~

~~Sensitivity for the following three conditions:~~

~~Collector orientation: South (0"), West (90"), North (180")~~

~~5. Weather~~

~~Sensitivity runs shall be made for three California Climate Zones: Zone 5 (Santa Maria), Zone 7 (San Diego), and Zone 13 (Fresno). All solar water heating programs certified for use in the Residential Building Standards must use the weather data as specified in Attachment I.~~

~~B. Passive Systems~~

~~The CEC has certified a calculation procedure for determining the annual performance of passive solar water heating systems (Attachment J). Passive solar water heating credits are derived from test results published by the Solar Rating and Certification Corporation (SRCC) in conjunction with climate zone specific weather data for California. Climate zone insolation data and ambient air temperature and water main temperature data are required to calculate passive solar credit. Applicants wishing to certify programs to be used for demonstrating compliance for passive type solar water heating systems must provide the CEC with all documentation specified in this certification package. The applicant's analysis methodology will be reviewed by CEC staff against the existing method.~~

~~Parameters which all passive solar water heating calculation methods must incorporate are the following:~~

~~(1) Qsav rating from SRCC test~~

~~(2) L rating from SRCC test.~~

~~(3) All fixed parameters as specified in Section V.~~

~~Table 2 lists SRCC Qsav, Qcap and L rating for most of the passive solar water heating systems currently listed with SRCC. For those systems that are not listed in the Table please contact SRCC or Florida Solar Energy Center for certification.~~

~~Solar Ra~~

~~c/o FSEC~~

~~1679 Clearlake Road~~

~~Cocoa, FL 32926~~

~~(407) 638-1537~~

~~(407) 63~~

~~SRCC@fsec.ucf.edu~~

~~VII. CERTIFICATION FORMS~~

~~See the attached forms.~~

~~Form 1~~

~~CALIFORNIA ENERGY RESOURCES~~

~~CONSERVATION AND DEVELOPMENT COMMISSION~~

~~APPLICATION FORM FOR CERTIFICATION OF AN ENERGY ANALYSIS COMPUTER PROGRAM~~

~~Part 1: General Information~~

~~1. Organization requesting certification:~~

~~*Name:* ______________________ *Phone:* (___) __________~~

~~Address: ______________________~~

~~______________________~~

~~Contact person: ______________________~~

~~Applicant signature: ______________________~~

~~Application date: ______________~~

~~2. Program Name: ______________________~~

~~3. The above named program is to be used for:~~

~~[ ] Space Conditioning [ ] Space Conditioning and Solar~~

~~[ ] Solar Water Heating Water Heating~~

~~4. Has the above-named program ever been used to analyze the energy use of a new residential building in California? [ ] YES [ ] NO~~

~~For Staff Use Only. Do Not Write Below These Lines.~~

~~1. Date received: ______________________~~

~~2. Application checklist: Complete Incomplete~~

~~Form 1 ______ ______~~

~~Form 2 ______ ______~~

~~Program Abstract ______ ______~~

~~Fixed Input Parameters ______ ______~~

~~Sensitivity Summary ______ ______~~

~~User's Manual ______ ______~~

~~3. Comments: ______________________~~

~~______________________~~

~~______________________~~

~~4. The above named program is certified for use in demonstrating compliance for California's Residential Building Regulations: [ ] YES [ ] NO~~

~~5. Staff signature: ____________________________ Date: ______________~~

~~6. Executive Director approval: __________________________ Date: ________________~~

~~Form 2~~

~~SENSITIVITY ANALYSIS~~

~~FOR INTERIM CERTIFICATION OF A SOLAR WATER HEATING ENERGY ANALYSIS COMPUTER PROGRAM~~

~~Program Name:~~ ______

~~Organization Name:~~ ______

~~*Applicant Name:*~~ ______

~~Run~~	~~Collector Area (sq.ft.)~~	~~Slope (FR-UL)~~	~~Y-intercept (FR-TAU-ALPHA)~~	~~Hot Water Use (Gal.)~~	~~Climate Zone~~	~~Annual S (0°)~~	~~F-Chart W (90°)~~	~~N (180°)~~	~~*Comparison* Program~~
~~1~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~5~~	~~.60~~			
~~2~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~7~~	~~.63~~			
~~3~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~13~~	~~.67~~			
~~4~~	~~48~~	~~.55~~	~~.75~~	~~50~~	~~5~~	~~.74~~			
~~5~~	~~48~~	~~.55~~	~~.75~~	~~50~~	~~7~~	~~.77~~			
~~6~~	~~48~~	~~.55~~	~~.75~~	~~50~~	~~13~~	~~.77~~			
~~7~~	~~48~~	~~1.25~~	~~.50~~	~~50~~	~~5~~	~~.37~~			
~~8~~	~~48~~	~~1.25~~	~~.50~~	~~50~~	~~7~~	~~.38~~			
~~9~~	~~48~~	~~1.25~~	~~.50~~	~~50~~	~~13~~	~~.44~~			
~~10~~	~~64~~	~~.70~~	~~.65~~	~~50~~	~~5~~	~~.71~~			
~~11~~	~~64~~	~~.70~~	~~.65~~	~~50~~	~~7~~	~~.74~~			
~~12~~	~~64~~	~~.70~~	~~.65~~	~~50~~	~~13~~	~~.76~~			
~~13~~	~~48~~	~~.70~~	~~.65~~	~~30~~	~~5~~	~~.72~~			
~~14~~	~~48~~	~~.70~~	~~.65~~	~~30~~	~~7~~	~~.75~~			
~~15~~	~~48~~	~~.70~~	~~.65~~	~~30~~	~~13~~	~~.77~~			
~~16~~	~~48~~	~~.70~~	~~.65~~	~~80~~	~~5~~	~~.48~~			
~~17~~	~~48~~	~~.70~~	~~.65~~	~~80~~	~~7~~	~~.50~~			

~~18~~	~~48~~	~~.70~~	~~.65~~	~~80~~	~~13~~	~~.55~~		
~~19~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~5~~		~~.53~~	~~.42~~
~~20~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~7~~		~~.55~~	~~.44~~
~~21~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~13~~		~~.60~~	~~.48~~
~~22~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~5~~			
~~23~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~7~~			
~~24~~	~~48~~	~~.70~~	~~.65~~	~~50~~	~~13~~			

~~TABLE 1~~

~~Solar Radiation~~

~~Climate Zone~~	~~Average Daily Temperature (°F)~~	~~Btu/ft²/day on horizontal surface~~	~~Btu/ft²/day on tilted surface*~~	~~Average Water Main Temperatures (°F)~~
~~1~~	~~52.1~~	~~1,241~~	~~1,340~~	~~60~~
~~2~~	~~57.9~~	~~1,535~~	~~1,658~~	~~65~~
~~3~~	~~56.9~~	~~1,559~~	~~1,684~~	~~65~~
~~4~~	~~59.6~~	~~1,606~~	~~1,734~~	~~65~~
~~5~~	~~60.3~~	~~1,623~~	~~1,753~~	~~65~~
~~6~~	~~63.5~~	~~1,596~~	~~1,724~~	~~70~~
~~7~~	~~62.9~~	~~1,619~~	~~1,748~~	~~70~~
~~8~~	~~63.0~~	~~1,637~~	~~1,768~~	~~70~~
~~9~~	~~63.6~~	~~1,618~~	~~1,747~~	~~70~~
~~10~~	~~63.3~~	~~1,777~~	~~1,919~~	~~70~~
~~11~~	~~62.8~~	~~1,580~~	~~1,706~~	~~65~~
~~12~~	~~60.3~~	~~1,641~~	~~1,772~~	~~65~~
~~13~~	~~62.3~~	~~1,708~~	~~1,845~~	~~65~~
~~14~~	~~55.9~~	~~1,841~~	~~1,988~~	~~65~~
~~15~~	~~72.6~~	~~1,858~~	~~2,007~~	~~70~~
~~16~~	~~42.8~~	~~1,656~~	~~1,788~~	~~60~~

~~* These values represent the correction for tilted surface based upon the ratio multiplier (1.08) of total horizontal radiation to total south facing radiation on a 30° tilt.~~

~~Table 2~~

~~Input Parameters for Passive Solar Water Heating Systems~~

~~**Company**~~	~~**Model**~~	~~**ID #**~~	~~**Volume (gal)**~~	~~**L (Btu/hr-F)**~~	~~**Q Save (Btu/day)**~~	~~**Q cap (Btu)**~~
~~Radco~~	~~CSHX60~~	~~94006A~~	~~60~~	~~5.3~~	~~20131~~	~~22466~~
~~Radco~~	~~CSHX80~~	~~94006B~~	~~80~~	~~6.8~~	~~23238~~	~~22466~~
~~Radco~~	~~CSHX100~~	~~94006C~~	~~100~~	~~8.4~~	~~24865~~	~~22466~~
~~Radco~~	~~CSHX40~~	~~94006D~~	~~40~~	~~3.8~~	~~15928~~	~~22466~~
~~SunEarth~~	~~CC-30~~	~~92011A~~	~~32~~	~~13.5~~	~~19889~~	~~22466~~
~~SunEarth~~	~~CC-40~~	~~92011B~~	~~42~~	~~17.0~~	~~22728~~	~~22466~~
~~SunEarth~~	~~CC-60P~~	~~92011C~~	~~64~~	~~28.4~~	~~28564~~	~~22466~~
~~SunEarth~~	~~CC-60S~~	~~92011D~~	~~64~~	~~16.8~~	~~28564~~	~~22466~~
~~SunEarth~~	~~CP-30~~	~~92011E~~	~~32~~	~~16.0~~	~~20016~~	~~22466~~
~~SunEarth~~	~~CP-40~~	~~92011F~~	~~42~~	~~20.1~~	~~22700~~	~~22466~~
~~SunEarth~~	~~CP-60P~~	~~92011G~~	~~64~~	~~33.6~~	~~27951~~	~~22466~~
~~SunEarth~~	~~CP-60S~~	~~92011H~~	~~64~~	~~16.8~~	~~28561~~	~~22466~~
~~TCT~~	~~PT-30-CN~~	~~95002A~~	~~30~~	~~13.7~~	~~21416~~	~~22466~~
~~TCT~~	~~PT-35-CN~~	~~95002B~~	~~35~~	~~13.7~~	~~21388~~	~~22466~~
~~TCT~~	~~PT-40-CN~~	~~95002C~~	~~40~~	~~17.7~~	~~26047~~	~~22466~~
~~TCT~~	~~PT-50-CN~~	~~95002D~~	~~50~~	~~17.7~~	~~25872~~	~~22466~~

~~Qsave = Energy Savings~~

~~L = Heat Loss Coefficient, UA~~

~~Qcap = Storage capacity of tank at 131°F~~

~~*VIII. ATTACHMENTS*~~

~~*ATTACHMENT A*~~

~~STANDARD INPUT~~

~~The input parameters shall be listed under the appropriate headings for clarity. When listing the parameters all units shall be specified. The following is a list of headings that shall be used:~~

1. ~~Collector Parameter~~
2. ~~Collector-Store-Transfer~~
3. ~~Storage Unit~~
4. ~~Load Parameters~~
5. ~~Loss Correction~~
6. ~~Weather~~

~~Additional parameters such as economic and auxiliary parameters may be used but shall be listed after the parameters listed above.~~

~~*ATTACHMENT B*~~

~~*STANDARD OUTPUT*~~

~~The standard output to be used for computer program certification purposes is defined as the solar contribution to the hot water load (including backup tank losses). This output shall be provided by all solar computer programs in kBtu/yr. Other system parameters may be shown on the standard data summary output summary but each output must contain at least the following:~~

~~System Type (See Attachment D)~~ ________________

~~Annual Delivered Energy~~ ________________~~KBtu/yr.~~

~~California Climate Zone~~ ________________

~~THERMAL PERFORMANCE~~

~~HT (MMBTU)~~	~~TA (°F)~~	~~HWLOAD (MMBTU)~~	~~QU (MMBTU)~~	~~QLOSS (MMBTU)~~	~~FDHW~~
		*	*	*	

~~Other output may be added here.~~

~~*ATTACHMENT C*~~

~~*WATER USE PROFILE*~~

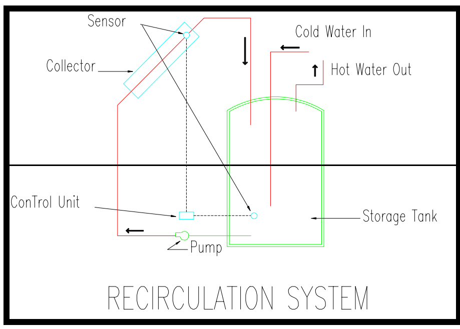
~~The following Table is a load profile of average water use by the hour for a given day. This must be a basic assumption in the calculations of an applicant's computer program.~~

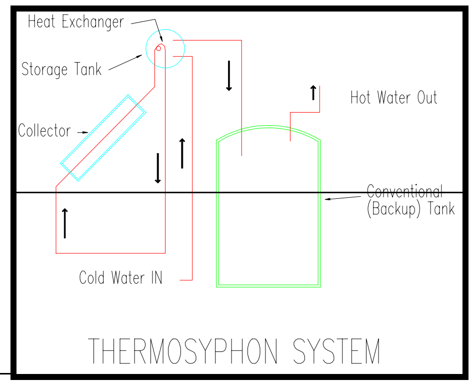
~~**Time of Day**~~	~~**% of Daily Water Use**~~	~~**Time of Day**~~	~~**% of Daily Water Use**~~
~~1AM~~	~~0~~	~~1PM~~	~~5.5~~
~~2AM~~	~~0~~	~~2PM~~	~~2.8~~
~~3AM~~	~~0~~	~~3PM~~	~~2.6~~
~~4AM~~	~~0~~	~~4PM~~	~~2.2~~
~~5AM~~	~~0~~	~~5PM~~	~~3.7~~
~~6AM~~	~~1.4~~	~~6PM~~	~~7.2~~
~~7AM~~	~~4.7~~	~~7PM~~	~~12.2~~
~~8AM~~	~~7.5~~	~~8PM~~	~~9.6~~
~~9AM~~	~~8.7~~	~~9PM~~	~~7.2~~
~~10AM~~	~~7.2~~	~~10PM~~	~~5.5~~
~~11AM~~	~~4.4~~	~~11PM~~	~~4.7~~
~~12PM~~	~~3.7~~	~~12AM~~	~~2.0~~

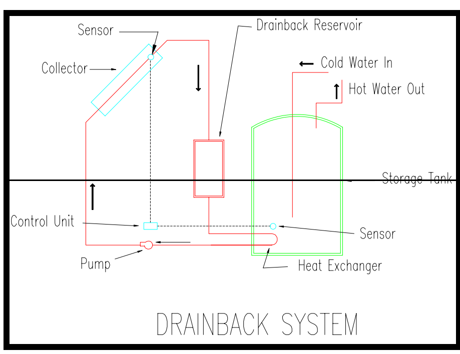
~~Average Time Distribution Of Water Usage is derived from Beckman, Klein, Duffie; Solar Heating Design By the F-Chart Method, John Wiley & Sons, Inc., New York, 1977, p.56.~~

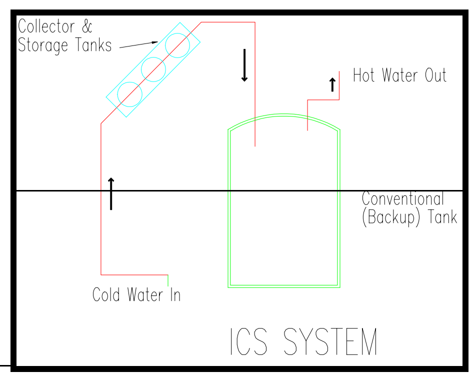
~~ATTACHMENT D~~

~~TYPICAL SOLAR WATER HEATING SYSTEMS~~

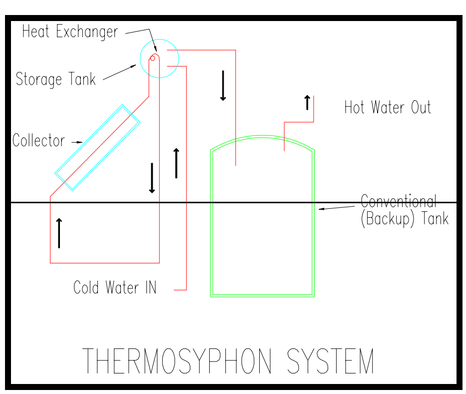






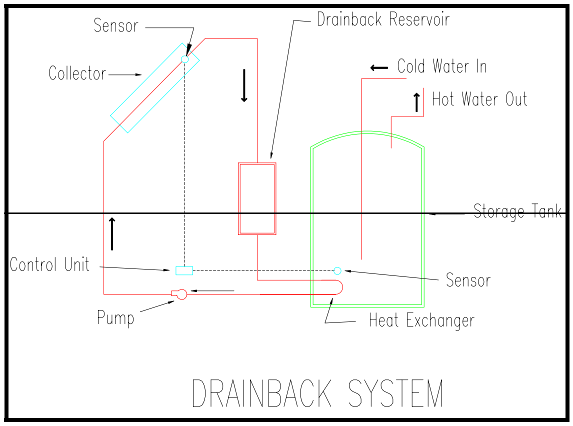


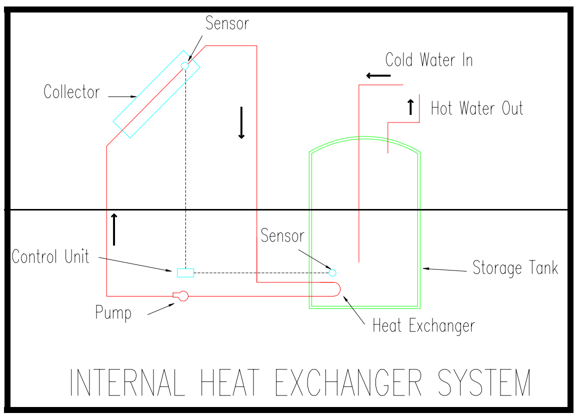
~~DIRECT ACTIVE SYSTEMS~~ ~~DIRECT PASSIVE SYSTEMS~~

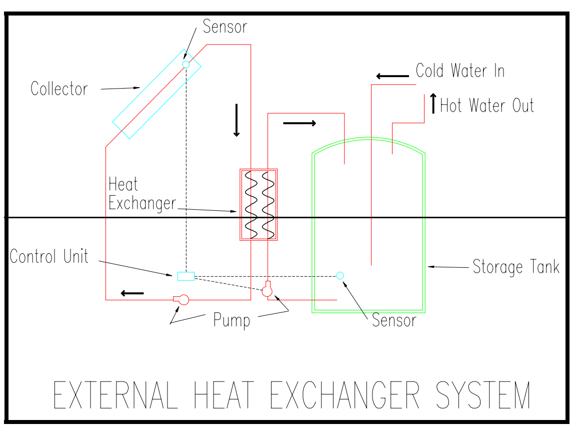


~~INDIRECT PASSIVE SYSTEMS~~

~~ATTACHMENT D -- cont'd.~~







~~INDIRECT ACTIVE SYSTEMS~~

~~ATTACHMENT E~~

~~F-Chart 4.1 Base Case Input Parameters~~

~~COLLECTOR PARAMETERS~~

~~C1. COLLECTOR AREA .... 48.00 FT2~~

~~C2. FR-UL PRODUCT .... .70 BTU/HR-FT2-DEG F~~

~~C3. FR-TAU-ALPHA (NORMAL INCIDENCE) .... .65~~

~~C6. NUMBER OF CURVERS .... 1.00~~

~~C7. INDEX OF REFRACTION .... 1.53~~

~~C8. EXTINCTION COEFFICIENT × LENGTH (KL) .... .04~~

~~C9. INCIDENCE ANGLE MODIFIER CONSTANT .... .00~~

~~C10. COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA .... 9.69 BTU/HR-FT2-DEG F~~

~~C12. COLLECTOR SLOPE .... 18.50 DEGREES~~

~~C13. COLLECTOR AZIMUTH .... .00 DEGREES~~

~~C14. GROUND REFLECTANCE.. .20~~

~~C15. INCIDENCE ANGLE MODIFIERS (10, 20, 30, 40, 50, 60, 70, 80, DEG.)~~

~~1.00 .99 .98 .95 .90 .80 .63 .37~~

~~COLLECTOR-STORE TRANSFER PARAMETERS~~

~~T2. UA OF COLLECTOR INLET PIPE OR DUCT .... 4.25 BTU/HR-DEG F~~

~~T3. UA OF COLLECTOR OUTLET PIPE OR DUCT .... 4.25 BTU/HR-DEG F~~

~~STORAGE UNIT PARAMETERS~~

~~S1. TANK CAPACITY/COLLECTOR AREA .... 13.88 BTU/DEG F-FT2~~

~~S2. STORAGE UNIT HEIGHT/DIAMETER RATIO .... 2.00~~

~~S3. HEAT LOSS COEFFICIENT... 08 BTU/HR-FT2-DEG F~~

~~S4. ENVIRONMENT TEMP. (-1000 FOR TENV=TAMB)... 68.00 DEG F~~

~~S5. HOT WATER AUXILIARY TANK UA .... 13.45 BTU/HR-DEG F~~

~~S6. HOT WATER AUX TANK ENVIRONMENT TEMP. .... 68.00 DEG F~~

~~LOAD PARAMETERS~~

~~L3. HOT WATER USE .... 50.00 GALLONS/DAY~~

~~L4. HOT WATER SET TEMPERATURE .... 140.00 DEG F~~

~~*L5. WATER MAINS TEMPERATU7E .... 65.00 DEG F*~~

~~AUXILIARY PARAMETERS~~

~~A3. HOT WATER AUXILIARY FUEL~~

~~(1=GAS, 2=ELEC, 3=OIL) .... 1.~~

~~A4. AUXILIARY WATER HEATER EFFICIENCY .... .76~~

~~ATTACHMENT F~~

~~F-Chart 4.1 Default Parameters~~

~~COLLECTOR PARAMETERS~~

~~C1. COLLECTOR AREA .... 538.20 FT2~~

~~C2. FR-UL PRODUCT.. .74 BTU/HR-FT2-DEG F~~

~~C3. FR-TAU-ALPHA (NORMAL INCIDENCE) .... .70~~

~~C4. CONCENTRATION RATIO .... 2.00~~

~~C5. CPC ACCEPTANCE HALF-ANGLE .... 30.00 DEGREES~~

~~C6. NUMBER OF COVERS (IF 0, CIS IS USED) .... 2.00~~

~~C7. INDEX OF REFRACTION... 1.53~~

~~C8. EXTINCTION COEFFICIENT X LENGTH (KL)....................... .04~~

~~C9. INC. ANGLE MOD. CONSTANT (IF 0, C6-C USED)............... .00~~

~~C10. COLLECTOR FLOW RATE & SPECIFIC HEAT/AREA........ 9.69 BTU/HR-FT2-DEG F~~

~~C11. TRACKING AXIS (1=EW, 2=NS, 3=2-AXIS) .... 3.00~~

~~C12. COLLECTOR SLOPE .... 43.00 DEGREES~~

~~C13. COLLECTOR AZIMUTH .... .00 DEGREES~~

~~C14. GROUND REFLECTANCE... .20~~

~~C15. INCIDENCE ANGLE MODIFIERS (10, 20, 30, 40, 50, 60, 70, 80 DEG.)~~

~~1.00 .99 .98 .95 .90 .80 .63 .37~~

~~COLLECTOR-STORE TRANSFER PARAMETERS~~

~~T1. EPS-CHIN OF COLLECTOR-STORE HX/COLLECTOR AREA 9.69 BTU/HR-FT2-DEG F~~

~~T2. UA OF COLLECTOR INLET PIPE OR DUCT .... .00 BTU/HR-DEG F~~

~~T3. UA OF COLLECTOR OUTLET PIPE OR DUCT..................... .00 BTU/HR-DEG F~~

~~T4. COLLECTOR DUCT LEAK RATE (PER CENT)...................... 15.00~~

~~T5. DUCT LEAK LOCATION (1=INLET, 2=OUTLET, 3=BOTH).... 3.00~~

~~STORAGE UNIT PARAMETERS~~

~~S1. TANK CAPACITY/COLLECTOR AREA.................................. 17.12 BTU/DEG F-T2~~

~~S2. STORAGE UNIT HEIGHT/DIAMETER RATIO .... 2.00~~

~~S3. HEAT LOSS COEFFICIENT.. .09 BTU/HR-FT2-DEG F~~

~~S4. ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB) 68.00 DEG F~~

~~S5. HOT WATER AUXILIARY TANK UA .... 7.58 BTU/HR-DEG F~~

~~S6. HOT WATER AUX TANK ENVIRONMENT TEMPERATURE . 68.00 DEG F~~

~~S7. ROCK BED CAPACITY/COLLECTOR AREA.......................... 17.12 BTU/DEG F-T2~~

~~S8. PHASE-CHANGE VOLUME/COLLECTOR AREA (X1000)..... 246.07 FT3/FT2~~

~~S9. PHASE-CHANGE MATERIAL DENSITY................................ 91.15 LB/FT3~~

~~S10. VOID FRACTION... .25~~

~~S11. SOLID PHASE SPECIFIC HEAT... .46 BTU/LB-DEG F~~

~~S12. LIQUID PHASE SPECIFIC HEAT....................................... .78 BTULB-DEG F~~

~~S13. HEAT OF MELTING .... 107.94 BTU/LB~~

~~S14. MELTING TEMPERATURE.. 89.60 DEG F~~

~~ATTACHMENT F-cont'd~~

~~DELIVERY DEVICE PARAMETERS~~

~~D1. EPS-CHIN OF LOAD HEAT EXCHANGER............................ 2274.72 BTU/HR-DEG F~~

~~D2. MINIMUM TEMPERATURE FOR HX OPERATION .... 68.00 DEG F~~

~~D3. DELIVERY HEAT PUMP NUMBER....................................... 2.00~~

~~D4. MINIMUM HEAT PUMP ABSORBER TEMPERATURE .... 50.00 DEG F~~

~~D5. HEAT PUMP BYPASS TEMPERATURE................................ 104.00 DEG F~~

~~LOAD PARAMETERS~~

~~L1. BUILDING UA.. 521.29 BTU/HR-DEG F~~

~~L2. ROOM TEMPERATURE.. 68.00 DEG F~~

~~L3. HOT WATER USE .... 79.26 GALLONS/DAY~~

~~L4. HOT WATER SET TEMPERATURE .... 140.00 DEG F~~

~~L5. WATER MAINS TEMPERATURE... 51.80 DEG F~~

~~L6. TOTAL PROCESS OR SPACE HEATING LOAD.................. 473.90 MBTU/DAY~~

~~L7. HOURS PER DAY .... 24.00~~

~~L8. LOAD RETURN TEMPERATURE .... 63.00 DEG F~~

~~AUXILIARY PARAMETERS~~

~~A1. AUXILIARY FUEL TYPE (1=GAS, 2=ELEC, 3=OIL) .... 2.~~

~~A2. AUXILIARY DEVICE EFFICIENT .... 1.00~~

~~A3. HOT WATER AUXILIARY FUEL (1=GAS, 2=ELEC, 3=OIL) ... 2.~~

~~A4. AUXILIARY WATER HEATER EFFICIENCY .... 1.00~~

~~A5. AUXILIARY HEAT PUMP NUMBER...................................... 1.~~

~~ECONOMIC PARAMETERS~~

~~E1. ECONOMIC OUTPUT DETAIL (1, 2 OR 3) .... 2.00~~

~~E2. REFERENCE OR COMPARISON SYSTEM (1 OR 2)............ 1.00~~

~~E3. CALCULATE RATE OF RETURN (YES=1, NO=2) .... 2.00~~

~~E4. INCOME PRODUCING BUILDING (YES=1, 2=NO)................ 2.00~~

~~E5. DEPRC: STR, LN,=1, DC,BAL.=2, SM-YR-DGT=3, NONE 4 . 1.00~~

~~E6. CONSIDER FEDERAL TAX CREDITS (YES=1, 2=NO).......... 1.00~~

~~E7. LENGTH OF ANALYSIS.. 20.00 YEARS~~

~~E8. TAX CREDITABLE SYSTEM BASE COST .... $6000.00~~

~~E9. NON-TAX CREDITABLE SYSTEM BASE COST .... $ .00~~

~~E10. ANNUAL INCREASE IN PURCHASED ENERGY DEMAND .00 %/YR~~

~~E11. TERM OF MORTGAGE.. 20.00 YEARS~~

~~E12. DOWN PAYMENT .... 10.00 %~~

~~E13. MORTGAGE ANNUAL INTEREST RATE (% OF ORIG. INV.) 8.00 %~~

~~E14. RESALE VALUE (% OF ORIGINAL INVESTMENT) .... .00 %~~

~~E15. ANNUAL NOMINAL (MARKET) DISCOUNT RATE .... 8.00 %~~

~~E16. EXTRA INSUR., MAINT. IN YEAR 1 (% OF ORIG. INV.)..... 1.00 %~~

~~E17. ANNUAL % INCREASE IN ABOVE EXPENSES................. 6.00 %~~

~~ATTACHMENT F-cont'd~~

~~E18. EFFECTIVE FEDERAL-STATE INCOME TAX RATE .... 35.00 %~~

~~E19. TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST .... 2.00 %~~

~~E20. ANNUAL % INCREASE IN PROPERTY TAX RATE .... 6.00 %/YR~~

~~E21. STATE CREDIT IN TIER ONE .... 24.00 %~~

~~E22. STATE CREDIT TIER ONE BREAK.................................... $10000.00~~

~~E23. STATE CREDIT IN TIER TWO.. .00 %~~

~~E24. STATE CREDIT TIER TWO BREAK .... $10000.00~~

~~E25. USEFUL LIFE FOR DEPREC. PURPOSES......................... 20.00 YEARS~~

~~E26. % OF ST. LINE DEP. RATE (DC. BAL. DEPRC.) .... 150.00 %~~

~~***ATTACHMENT G***~~

~~F-Chart 4.0 Input Parameters~~

~~for the Solar Sizing Charts~~

~~Pursuant to the Residential Building Standards~~

~~COLLECTOR PARAMETERS~~

~~C1.~~	~~COLLECTOR AREA~~	~~VARIES~~
~~C2.~~	~~FR-UL PRODUCT~~	~~VARIES~~
~~C3.~~	~~FR-TAU-ALPHA (NORMAL INCIDENCE)~~	~~VARIES~~
~~C6.~~	~~NUMBER OF COVERS~~	~~1.00~~
~~C7.~~	~~INDEX OF REFRACTION~~	~~1.53~~
~~C8.~~	~~EXTINCTION COEFFICIENT X LENGTH (KL)~~	~~0.04~~
~~C9.~~	~~INCIDENCE ANGLE MODIFIER CONSTANT~~	~~0.0~~
~~C10.~~	~~COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA~~	~~9.69 BTU/HR-FT2-DEG F~~
~~C12.~~	~~COLLECTOR SLOPE~~	~~18.50 DEGREES~~
~~C13.~~	~~COLLECTOR AZIMUTH~~	~~0.00 DEGREES~~
~~C14.~~	~~GROUND REFLECTANCE~~	~~0.20 DEGREES~~

~~COLLECTOR-STORE TRANSFER PARAMETERS~~

~~T2.~~	~~UA OF COLLECTOR INLET PIPE OR DUCT~~	~~4.25 BTU/HR/DEG F~~
~~T3.~~	~~UA OF COLLECTOR OUTLET PIPE OR DUCT~~	~~4.25 BTU/HR-DEG F~~

~~STORAGE UNIT PARAMETERS~~

~~S1.~~	~~TANK CAPACITY/COLLECTOR AREA~~	~~10.40 BTU/DEG F-FT^2~~
~~S2.~~	~~STORAGE UNIT HEIGHT/DIAMETER RATIO~~	~~2.14~~
~~S3.~~	~~HEAT LOSS COEFFICIENT~~	~~0.08 BTU/HR-FT^2-DEG~~
~~S4.~~	~~ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB)~~	~~68.00 DEG F~~
~~S5.~~	~~HOT WATER AUXILIARY TANK UA~~	~~13.45 BTU/HR-DEG F~~
~~S6.~~	~~HOT WATER AUX TANK ENVIRONMENT TEMPERATURE~~	~~68.00 DEG F~~

~~LOAD PARAMETERS~~

~~L3.~~	~~HOT WATER USE~~	~~50.00 GALLONS/DAY~~
~~L4.~~	~~HOT WATER SET TEMPERATURE~~	~~140.00 DEG F~~

~~L5. WATER MAINS TEMPERATURE .... VARIES BY CLIMATE ZONE~~

~~AUXILIARY PARAMETERS~~

~~A3. HOT WATER AUXILIARY FUEL (1=GAS, 2=ELEC, 3=OIL) 1.~~

~~A4. AUXILIARY WATER HEATER EFFICIENCY .... 0.76~~

~~ATTACHMENT H~~

~~F-Chart 4.0 Assumptions~~

~~Used for Residential~~

~~Solar Domestic Hot Water Sizing Tables~~

1. ~~Two-tank gas backup solar system~~

2. ~~C12: collectors are mounted flush on the roof, with a pitch of 4 in 12~~

3. ~~T2 and T3 assumes heat losses from the collector to storage piping (2.5 feet of outside piping with 3/4 inch insulation, nominal pipe diameter of 3/4 inch; and 15 feet of inside piping with 1/2 inch insulation on the collector inlet).~~

~~T2 = (.31 Btu/hr - ft² – °F) × (.6 ft²/ft) × 2.5 +~~

~~(.51 Btu/hr - ft² – °F) × (.49 ft²/ft) × 15~~

~~Therefore~~

$$T2 = UA = \frac{4.25\,Btu}{hr - {}^{\circ}F}$$

4. ~~S1: 82 gallon storage tank.~~

5. ~~S5: Assumes pump parasitic losses, backup tank skin and pilot light losses, and corrected for electrical resource energy line losses.~~

~~Pump Energy = 85 W~~ pump ~~× 6 hrs/day x 365 days/yr x 10,239 Btu/Wh~~

~~= 1,906,000Btu/year~~

Tank ~~Standby Losses (include pilot energy loss and standby loss of 3.3 percent/hour) :~~

$$\left[24h/d - \frac{\left(15.0 \times 10^{6}\,Btu/yr\right)}{365d/yr \times 40{,}000\,Btu/h}\right] \times 365d/yr \times \left(8.25\,Btu/gal \times {}^{\circ}F\right) \times .033/h \times 40gal \times (140-68)^{\circ}F$$

~~= 6,574,500 Btu/year~~

~~Therefore Hot Water Auxiliary Tank UA :~~

$$\frac{(1{,}906{,}000 + 6{,}574{,}500)Btu / year}{8{,}760 hour / year \times (140 - 68)^\circ F} \cancel{= UA = 13.45\ \text{Btu/hr-}^\circ\text{F}}$$

6. ~~L3: Household hot water load - 50 gal./day~~

7. ~~L4: Hot water set temperature - 140°F.~~

8. ~~A4: Gas backup tank efficiency - 76%~~

~~ATTACHMENT I~~

~~Climate Zone Weather Data~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~245~~	~~TITLE 24 ZONE 1~~	~~CA~~	~~41.00~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~663.8~~	~~760.8~~	~~1046.8~~	~~1641.7~~	~~1874.6~~	~~2103.5~~
~~1947.6~~	~~1462.7~~	~~1115.8~~	~~803.8~~	~~612.9~~	~~497.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST~~

~~637.2~~	~~489.6~~	~~543.6~~	~~462.6~~	~~408.6~~	~~358.2~~
~~313.2~~	~~198.0~~	~~214.2~~	~~313.2~~	~~379.8~~	~~496.8~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~42.8~~	~~48.2~~	~~46.4~~	~~50.0~~	~~51.8~~	~~53.6~~
~~53.6~~	~~57.2~~	~~57.2~~	~~53.6~~	~~51.8~~	~~48.2~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~246~~	~~TITLE 24 ZONE 2~~	~~CA~~	~~38.50~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~752.8~~	~~1082.8~~	~~1477.7~~	~~2033.6~~	~~2120.6~~	~~2429.5~~
~~2488.5~~	~~2092.6~~	~~1792.6~~	~~1262.7~~	~~829.9~~	~~610.8~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST~~

~~586.8~~	~~426.6~~	~~385.2~~	~~277.2~~	~~158.4~~	~~79.2~~
~~32.4~~	~~21.6~~	~~45.0~~	~~158.4~~	~~349.2~~	~~531.0~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~44.6~~	~~48.2~~	~~51.8~~	~~55.4~~	~~59.0~~	~~64.4~~
~~66.2~~	~~64.4~~	~~64.4~~	~~59.0~~	~~51.8~~	~~46.4~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~247~~	~~TITLE 24 ZONE 3~~	~~CA~~	~~37.70~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~843.9~~	~~904.8~~	~~1443.7~~	~~2040.5~~	~~2272.5~~	~~2392.5~~
~~2306.6~~	~~2087.5~~	~~1580.7~~	~~1086.7~~	~~843.9~~	~~590.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~518.4~~	~~410.4~~	~~403.2~~	~~207.0~~	~~223.2~~	~~120.8~~
~~111.6~~	~~41.4~~	~~102.6~~	~~144.0~~	~~262.8~~	~~478.8~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~48.2~~	~~50.0~~	~~51.8~~	~~57.2~~	~~57.2~~	~~60.8~~
~~60.8~~	~~62.6~~	~~60.8~~	~~59.0~~	~~55.4~~	~~48.2~~

~~ATTACHMENT I cont'd.~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~248~~	~~TITLE 24 ZONE 4~~	~~CA~~	~~37.40~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~766.8~~	~~1099.8~~	~~1491.7~~	~~2046.6~~	~~2125.6~~	~~2431.5~~
~~2492.5~~	~~2100.6~~	~~1808.7~~	~~1280.7~~	~~843.9~~	~~622.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~527.4~~	~~318.6~~	~~372.6~~	~~253.8~~	~~255.6~~	~~72.0~~
~~34.2~~	~~21.6~~	~~64.8~~	~~147.6~~	~~331.2~~	~~534.6~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~46.4~~	~~53.6~~	~~51.8~~	~~57.2~~	~~57.2~~	~~64.4~~
~~66.2~~	~~66.2~~	~~64.4~~	~~60.8~~	~~53.6~~	~~48.2~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~249~~	~~TITLE 24 ZONE 5~~	~~CA~~	~~34.90~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~843.9~~	~~1100.7~~	~~1549.7~~	~~1919.6~~	~~2043.6~~	~~2394.5~~
~~2368.5~~	~~2108.6~~	~~1687.6~~	~~1365.7~~	~~931.8~~	~~801.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~464.4~~	~~381.6~~	~~354.6~~	~~313.2~~	~~248.4~~	~~216.0~~
~~91.8~~	~~93.6~~	~~106.2~~	~~163.8~~	~~246.6~~	~~363.6~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~48.2~~	~~51.8~~	~~53.6~~	~~53.6~~	~~57.2~~	~~57.2~~
~~60.8~~	~~60.8~~	~~60.8~~	~~59.0~~	~~55.4~~	~~51.8~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~250~~	~~TITLE 24 ZONE 6~~	~~CA~~	~~33.80~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~916.8~~	~~1282.8~~	~~1593.7~~	~~1949.6~~	~~1992.6~~	~~2123.5~~
~~2312.5~~	~~2089.6~~	~~1682.7~~	~~1358.7~~	~~1011.8~~	~~874.8~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~338.4~~	~~262.8~~	~~194.4~~	~~138.6~~	~~95.4~~	~~.0~~

~~.0~~	~~.0~~	~~1.8~~	~~18.0~~	~~120.6~~	~~315.0~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~53.6~~	~~55.4~~	~~59.0~~	~~60.8~~	~~62.6~~	~~68.0~~
~~71.6~~	~~73.4~~	~~71.6~~	~~66.2~~	~~60.8~~	~~55.4~~

~~ATTACHMENT I cont'd.~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~251~~	~~TITLE 24 ZONE 7~~	~~CA~~	~~32.70~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~1012.8~~	~~1142.8~~	~~1575.6~~	~~1869.6~~	~~2031.6~~	~~1927.5~~
~~2232.5~~	~~2130.6~~	~~1749.6~~	~~1387.7~~	~~997.6~~	~~871.5~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~268.2~~	~~246.6~~	~~297.0~~	~~122.4~~	~~91.8~~	~~46.8~~
~~1.8~~	~~.0~~	~~1.8~~	~~32.4~~	~~163.8~~	~~262.8~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~55.4~~	~~55.4~~	~~55.4~~	~~60.8~~	~~60.8~~	~~62.6~~
~~66.2~~	~~69.8~~	~~66.2~~	~~64.4~~	~~59.0~~	~~55.4~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~252~~	~~TITLE 24 ZONE 8~~	~~CA~~	~~33.70~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~974.8~~	~~1205.7~~	~~1636.7~~	~~2077.6~~	~~2249.5~~	~~2180.5~~
~~2477.5~~	~~2202.5~~	~~1890.6~~	~~1429.7~~	~~992.8~~	~~958.5~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~370.8~~	~~280.8~~	~~199.8~~	~~126.0~~	~~66.6~~	~~5.4~~
~~3.6~~	~~.0~~	~~.0~~	~~41.4~~	~~178.2~~	~~243.0~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~51.8~~	~~53.6~~	~~57.2~~	~~60.8~~	~~64.4~~	~~66.2~~
~~71.6~~	~~69.8~~	~~71.6~~	~~64.6~~	~~57.2~~	~~57.2~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATTITUDE~~
~~253~~	~~TITLE 24 ZONE 9~~	~~CA~~	~~34.30~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~964.8~~	~~1196.8~~	~~1530.7~~	~~2072.6~~	~~2248.5~~	~~2184.6~~
~~2477.5~~	~~2200.6~~	~~1884.6~~	~~1421.7~~	~~983.8~~	~~946.8~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~352.8~~	~~318.6~~	~~266.4~~	~~171.0~~	~~79.2~~	~~3.6~~
~~1.8~~	~~.0~~	~~1.8~~	~~46.8~~	~~127.8~~	~~329.4~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

	~~51.8~~	~~51.8~~	~~53.6~~	~~59.0~~	~~62.6~~	~~64.4~~
	~~71.6~~	~~69.8~~	~~68.0~~	~~62.6~~	~~59.0~~	~~53.6~~

~~***ATTACHMENT I cont'd.***~~

~~CALL NO. CITY STATE LATTITUDE~~

~~254 TITLE 24 ZONE 10 CA 33.90~~

~~SOLAR DATA FOR SURFACE SLOPE=.00 AZIMUTH=.00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~891.8 1212.8 1604.7 1926.6 2021.6 2195.6~~

~~2276.5 2085.6 1796.6 1360.7 1070.8 892.3~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~408.6 347.4 286.2 194.4 102.6 30.6~~

~~.0 .0 5.4 32.4 169.2 349.2~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~51.8 51.8 55.4 59.0 64.4 69.8~~

~~75.2 77.0 73.4 66.2 57.2 53.8~~

~~CALL NO. CITY STATE LATITUDE~~

~~255 TITLE 24 ZONE 11 CA 40.20~~

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~568.8 866.8 1318.7 1952.6 2338.5 2541.6~~

~~2685.4 2350.5 1855.6 1250.7 736.8 492.9~~

~~LONG TERM MONTHLY AVERAGE DEG=F DAYS, JAN FIRST.~~

~~667.8 424.8 421.2 221.4 43.2 7.2~~

~~.0 .0 10.8 81.0 403.2 608.49~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG F, JAN FIRST.~~

~~42.8 50.0 51.8 57.2 68.0 77.0~~

~~82.4 80.6 75.2 64.4 51.8 44.6~~

~~CALL NO. CITY STATE LATITUDE~~

~~256 TITLE 24 ZONE 12 CA 38.50~~

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~700.9 752.8 1476.7 2193.5 2453.5 2812.4~~

~~2718.5 2422.5 1938.6 1108.7 879.9 474.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~725.4 496.8 439.2 133.2 93.6 7.2~~

~~.0 .0 3.6 104.4 311.4 592.2~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG-F, JAN FIRST.~~

~~41.0~~	~~46.4~~	~~50.0~~	~~60.8~~	~~60.8~~	~~69.8~~
~~71.6~~	~~73.4~~	~~68.0~~	~~60.8~~	~~53.6~~	~~44.6~~

~~ATTACHMENT I cont'd.~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATITUDE~~
~~257~~	~~TITLE 24 ZONE 13~~	~~CA~~	~~36.80~~

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~669.8~~	~~1032.8~~	~~1589.6~~	~~2116.6~~	~~2501.5~~	~~2720.4~~
~~2707.5~~	~~2398.5~~	~~2023.5~~	~~1455.7~~	~~910.8~~	~~569.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~653.4~~	~~421.2~~	~~277.2~~	~~190.8~~	~~39.6~~	~~7.2~~
~~.0~~	~~.0~~	~~10.8~~	~~59.4~~	~~358.2~~	~~682.2~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG-F, JAN FIRST.~~

~~42.8~~	~~50.0~~	~~55.4~~	~~59.0~~	~~68.0~~	~~77.0~~
~~82.4~~	~~78.8~~	~~73.4~~	~~64.4~~	~~51.8~~	~~42.8~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATITUDE~~
~~258~~	~~TITLE 24 ZONE 14~~	~~CA~~	~~35.70~~

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~877.8~~	~~1187.8~~	~~1722.7~~	~~2278.6~~	~~2585.4~~	~~2732.5~~
~~2581.5~~	~~2459.5~~	~~1985.6~~	~~1504.7~~	~~1022.8~~	~~883.8~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~707.4~~	~~457.2~~	~~171.0~~	~~104.4~~	~~19.8~~	~~.0~~
~~.0~~	~~.0~~	~~.0~~	~~52.2~~	~~372.6~~	~~604.8~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG-F, JAN FIRST.~~

~~41.0~~	~~48.2~~	~~59.0~~	~~64.4~~	~~71.6~~	~~86.0~~
~~89.6~~	~~86.0~~	~~80.6~~	~~66.2~~	~~51.8~~	~~44.6~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATITUDE~~
~~259~~	~~TITLE 24 ZONE 15~~	~~CA~~	~~32.80~~

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~1150.7~~	~~1428.7~~	~~1830.6~~	~~2326.5~~	~~2533.5~~	~~2632.4~~
~~2373.5~~	~~2280.5~~	~~2032.6~~	~~1590.7~~	~~1274.8~~	~~1050.8~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~334.8~~	~~203.4~~	~~106.2~~	~~30.6~~	~~.0~~	~~.0~~
~~.0~~	~~.0~~	~~.0~~	~~.0~~	~~73.8~~	~~281.0~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG-F, JAN FIRST.~~

~~53.6~~	~~57.2~~	~~64.4~~	~~71.6~~	~~78.8~~	~~86.0~~
~~91.4~~	~~91.4~~	~~86.0~~	~~75.2~~	~~62.6~~	~~55.4~~

~~ATTACHMENT I cont'd.~~

~~CALL NO.~~	~~CITY~~	~~STATE~~	~~LATITUDE~~		
~~260~~	~~TITLE 24 ZONE 16~~	~~CA~~	~~41.30~~		

~~SOLAR DATA FOR SURFACE SLOPE = .00 AZIMUTH = .00~~

~~DATA IN BTU/FT2/DAY, LISTED JAN FIRST~~

~~568.8~~	~~798.9~~	~~1309.7~~	~~1779.6~~	~~2198.5~~	~~2480.5~~
~~2602.4~~	~~2234.6~~	~~1786.7~~	~~1168.8~~	~~599.8~~	~~527.9~~

~~LONG TERM MONTHLY AVERAGE DEG-F DAYS, JAN FIRST.~~

~~1004.4~~	~~720.0~~	~~646.2~~	~~543.6~~	~~304.2~~	~~156.6~~
~~30.6~~	~~64.8~~	~~111.6~~	~~437.4~~	~~687.6~~	~~878.4~~

~~LONG TERM MONTHLY AVERAGE AMBIENT TEMPERATURE, DEG-F, JAN FIRST.~~

~~32.0~~	~~39.2~~	~~44.6~~	~~46.4~~	~~55.4~~	~~62.6~~
~~71.6~~	~~68.0~~	~~62.6~~	~~51.8~~	~~42.8~~	~~37.4~~

~~*ATTACHMENT J*~~

~~DETERMINING ENERGY SAVINGS FROM A PASSIVE SOLAR WATER HEATER (ALTERNATIVE CALCULATION METHOD FOR PASSIVE SOLAR CREDIT)~~

~~Calculating the performance of a passive solar water heater is done by using test results published by the Solar Rating & Certification Corporation (SRCC) for passive solar water heaters and calculating the amount of energy which can be contributed by the equipment using local weather data. The calculation method is as follows:~~

~~Step 1. Calculate temperature difference from SRCC data:~~

~~$T_{SRCC} = [Q_{SAV} /(100 \text{ gal/day} \times 8.25 \text{ Btu/gal-}^{\circ}\text{F})] + [Q_{CAP} /(V_t \times 8.25 \text{ Btu/gal-}^{\circ}\text{F})]$~~

~~Where: Q_{SAV} (Btu/day) = from SRCC test results~~

~~Q_{CAP} (Btu) = from SRCC test results~~

~~V_t (gal) = total volume of solar storage tank~~

~~Step 2. Calculate energy losses during SRCC test:~~

~~$Q_{LOSS,\ SRCC} = T_{SRCC} \times 16 \text{ hr/day} \times L \text{ Btu/hr-}^{\circ}\text{F}$~~

~~Where: 16 = number of hours system is losing heat~~

~~L (Heat Loss Coefficient, Btu/hr-°F from SRCC test results)~~

~~Step 3. Calculate energy collected during the SRCC test:~~

~~$Q_{TOTAL,\ SRCC} = Q_{SAV} + Q_{LOSS,\ SRCC}$~~

~~Step 4. Adjust energy collected to climate zone insolation values (see Table J-1)~~

~~$Q_{TOTAL,\ LOCAL} = 1204 + [(Q_{TOTAL,\ SRCC} - 1204)/1500] \times \text{CZ insolation}$~~

~~Table J-1~~

~~Climate Zone~~	~~CZ Insolation~~	~~Climate Zone~~	~~CZ Insolation~~
~~1~~	~~1340~~	~~9~~	~~1747~~
~~2~~	~~1658~~	~~10~~	~~1919~~

~~3~~	~~1684~~	~~11~~	~~1706~~
~~4~~	~~1734~~	~~12~~	~~1772~~
~~5~~	~~1753~~	~~13~~	~~1845~~
~~6~~	~~1724~~	~~14~~	~~1988~~
~~7~~	~~1748~~	~~15~~	~~2007~~
~~8~~	~~1768~~	~~16~~	~~1788~~

~~Step 5. Determine~~ ~~$T_{TANK, LOCAL}$, average tank temperature delivered to the site:~~

~~$Q_{TOTAL, LOCAL}$ = (50 gal/day) x (8.25 Btu/gal-°F) x ($T_{TANK, LOCAL}$ - CZ Water Main Temp) + 16 hrs/day x L x ($T_{TANK, LOCAL}$ - CZ Ambient Air Temp)~~

~~Solving for $T_{TANK, LOCAL}$:~~

~~$T_{TANK, LOCAL}$ = (A_1 + A_2 + $Q_{TOTAL, LOCAL}$) / (A_3 + A_4)~~

~~Where: A_1 = (50 gal/day) x (8.25 Btu/gal-°F) x (CZ Water Main Temp)~~

~~A_2 = 16 hrs/day x L x (CZ Ambient Air Temp)~~

~~A_3 = (50 gal/day) x (8.25 Btu/gal-°F)~~

~~A_4 = 16 hrs/day x L~~

~~CZ Water Main Temp and CZ Ambient Air Temp from Table J-2~~

~~Table J-2~~

~~Climate Zone Water Main & Ambient Air Temp~~

~~Climate Zone~~	~~Ambient Air Temp °F~~	~~Water Main Temp °F~~
~~1~~	~~52.1~~	~~60~~
~~2~~	~~57.9~~	~~65~~
~~3~~	~~56.9~~	~~65~~
~~4~~	~~59.6~~	~~65~~
~~5~~	~~60.3~~	~~65~~
~~6~~	~~63.5~~	~~70~~
~~7~~	~~62.9~~	~~70~~
~~8~~	~~63~~	~~70~~
~~9~~	~~63.6~~	~~70~~
~~10~~	~~63.3~~	~~70~~
~~11~~	~~62.8~~	~~65~~
~~12~~	~~60.3~~	~~65~~
~~13~~	~~62.3~~	~~65~~
~~14~~	~~55.9~~	~~65~~
~~15~~	~~72.6~~	~~70~~

~~16~~	~~42.8~~	~~60~~

~~Step 6. Determine energy losses at the site:~~

~~$Q_{LOSS, LOCAL} = L \times 16 \text{ hrs} \times (T_{TANK, LOCAL} - \text{CZ Ambient Air Temp})$~~

~~Step 7. Determine energy used by electric resistance freeze protection devices:~~

~~ERP = (Freeze days/yr + 4) x (Collector Area) x (0.5 kBtu /ft² -freeze day)~~

~~This is calculated only if the system uses electric resistance freeze protection.~~

~~Step 8. Calculate system total annual energy contribution (mmBtu/yr):~~

~~$\{(Q_{TOTAL, LOCAL} - Q_{LOSS, LOCAL}) \times 0.365 \times 0.001 - ERP\} \times$ (No. of Dwelling Units)~~

~~Step 9. Calculate Standard Recovery Load, SRL (mmBtu/yr):~~

$$SRL_k = \sum_{i=1}^{n} \{0.0855347(CFA_i/1000)^2 + 3.61307\,(CFA_i/1000) + 6.036\}/\text{number of systems}$$

~~Step 10: Determine Distribution System Credit/Penalty:~~

~~Select Distribution System Credit/Penalty from Table J-3.~~

~~Table J-3: Distribution System Credit/Penalty[1] (per worksheet)~~

~~Standard Recovery Load~~	~~Point-of-Use~~	~~Hot Water Recovery[1]~~	~~Pipe Insulation[1]~~	~~Recirculation Systems: Time/Temp~~	~~Demand~~	~~Time~~	~~Temp~~	~~Cont~~
~~< 6.3~~	~~1.1~~	~~1.1~~	~~0.5~~	~~0.2~~	~~0.1~~	~~-1.7~~	~~-0.3~~	~~-3.1~~
~~6.3 - 6.99~~	~~1.2~~	~~1.2~~	~~0.5~~	~~0.2~~	~~0.1~~	~~-1.8~~	~~-0.3~~	~~-3.4~~
~~7.0 - 7.49~~	~~1.3~~	~~1.3~~	~~0.5~~	~~0.3~~	~~0.1~~	~~-1.9~~	~~-0.4~~	~~-3.7~~
~~7.5 - 7.99~~	~~1.4~~	~~1.4~~	~~0.6~~	~~0.3~~	~~0.1~~	~~-2.1~~	~~-0.4~~	~~-3.9~~
~~8.0 - 8.49~~	~~1.5~~	~~1.5~~	~~0.6~~	~~0.3~~	~~0.1~~	~~-2.2~~	~~-0.4~~	~~-4.2~~
~~8.5 - 8.99~~	~~1.6~~	~~1.6~~	~~0.6~~	~~0.3~~	~~0.1~~	~~-2.3~~	~~-0.4~~	~~-4.4~~
~~9.0 - 9.49~~	~~1.7~~	~~1.7~~	~~0.7~~	~~0.3~~	~~0.2~~	~~-2.5~~	~~-0.5~~	~~-4.7~~
~~9.5 - 9.99~~	~~1.7~~	~~1.7~~	~~0.7~~	~~0.4~~	~~0.2~~	~~-2.6~~	~~-0.5~~	~~-5.0~~
~~10.0 - 10.99~~	~~1.8~~	~~1.8~~	~~0.8~~	~~0.4~~	~~0.2~~	~~-2.8~~	~~-0.5~~	~~-5.2~~
~~11.0 - 11.99~~	~~2.0~~	~~2.0~~	~~0.8~~	~~0.4~~	~~0.2~~	~~-3.0~~	~~-0.6~~	~~-5.7~~

~~12.0 - 12.99~~	~~2.2~~	~~2.2~~	~~0.9~~	~~0.5~~	~~0.2~~	~~-3.3~~	~~-0.6~~	~~-6.3~~
~~13.0 - 13.99~~	~~2.4~~	~~2.4~~	~~1.0~~	~~0.5~~	~~0.2~~	~~-3.6~~	~~-0.7~~	~~-6.8~~
~~14.0 - 15.99~~	~~2.6~~	~~2.6~~	~~1.1~~	~~0.5~~	~~0.2~~	~~-3.9~~	~~-0.7~~	~~-7.3~~
~~16.0 - 17.99~~	~~2.9~~	~~2.9~~	~~1.2~~	~~0.6~~	~~0.3~~	~~-4.4~~	~~-0.8~~	~~-8.4~~
~~18.0 - 19.99~~	~~3.3~~	~~3.3~~	~~1.4~~	~~0.7~~	~~0.3~~	~~-5.0~~	~~-0.9~~	~~-9.4~~
~~20.0 - 21.99~~	~~3.7~~	~~3.7~~	~~1.5~~	~~0.8~~	~~0.3~~	~~-5.5~~	~~-1.0~~	~~-10.4~~
~~22.0 - 23.99~~	~~4.0~~	~~4.0~~	~~1.7~~	~~0.8~~	~~0.4~~	~~-6.1~~	~~-1.1~~	~~-11.5~~
~~24.0 - 25.99~~	~~4.4~~	~~4.4~~	~~1.8~~	~~0.9~~	~~0.4~~	~~-6.6~~	~~-1.2~~	~~-12.5~~
~~26.0+~~	~~4.8~~	~~4.8~~	~~2.0~~	~~1.0~~	~~0.4~~	~~-7.2~~	~~-1.4~~	~~-13.6~~

~~1. Hot water recovery and pipe insulation credits may only be applied to non-recirculating systems and demand recirculating systems. All other recirculating systems must have pipe insulation.~~

~~Step 11: Adjust Recovery Load:~~

~~Adjust Recovery Load = SRL (from Step 9) - Distribution System Credit/Penalty (from Step 10) - System total annual energy contribution (from Step 8)~~

~~The adjusted recovery load must be greater than 3 mmBtu/yr, (if the result is less than 3 assign a value of three.)~~

~~Step 12: Estimate Basic Energy Use~~

~~Estimate basic energy use using the adjust recovery load from step 11 and Table J-4~~

~~Step 13: Calculate water heating energy budget (mmBtu/yr):~~

~~Water heating energy budget = 0.00485 x~~ $\cancel{\sum^{N} CFA_i}$ ~~+ 16.37 N~~

~~Step14: Calculate Solar Savings Fraction:~~

~~Solar Savings Fraction = 1 - Basic Energy Use (Step 12) / Water Heating Energy Budget (Step 13)~~

~~Table J-4A: Basic Energy Use (BEU) - Storage Gas Heater [no interpolation]~~

~~Adjuste~~	~~Energy Factor~~																						
~~Load~~	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.74	0.78	0.82
3.0	19.9	18.5	17.3	16.2	15.3	14.4	13.7	13.0	12.4	11.8	11.3	10.8	10.4	10.0	9.3	8.7	8.1	7.7	7.2	6.8	6.2	5.7	5.2
3.2	19.6	18.3	17.2	16.2	15.3	14.5	13.8	13.1	12.6	12.0	11.5	11.1	10.6	10.3	9.6	8.9	8.4	7.9	7.5	7.1	6.5	5.9	5.5
3.4	19.4	18.2	17.2	16.2	15.4	14.6	14.0	13.3	12.8	12.2	11.8	11.3	10.9	10.5	9.8	9.2	8.7	8.2	7.8	7.4	6.7	6.2	5.7
3.6	19.3	18.2	17.2	16.3	15.5	14.8	14.2	13.6	13.0	12.5	12.0	11.6	11.2	10.8	10.1	9.5	9.0	8.5	8.1	7.7	7.0	6.4	5.9
3.8	19.3	18.2	17.3	16.5	15.7	15.0	14.4	13.8	13.2	12.7	12.3	11.8	11.4	11.1	10.4	9.8	9.2	8.8	8.3	7.9	7.3	6.7	6.2
4.0	19.3	18.3	17.4	16.6	15.9	15.2	14.6	14.0	13.5	13.0	12.5	12.1	11.7	11.3	10.7	10.1	9.5	9.0	8.6	8.2	7.5	6.9	6.4
4.2	19.4	18.4	17.6	16.8	16.1	15.4	14.8	14.2	13.7	13.2	12.8	12.4	12.0	11.6	10.9	10.3	9.8	9.3	8.9	8.5	7.8	7.2	6.7
4.4	19.5	18.6	17.7	17.0	16.3	15.6	15.0	14.5	14.0	13.5	13.1	12.6	12.3	11.9	11.2	10.6	10.1	9.6	9.1	8.7	8.0	7.4	6.9
4.6	19.6	18.7	17.9	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.2	11.5	10.9	10.3	9.8	9.4	9.0	8.3	7.7	7.1
4.8	19.8	18.9	18.1	17.4	16.7	16.1	15.5	15.0	14.5	14.0	13.6	13.2	12.8	12.4	11.8	11.2	10.6	10.1	9.7	9.3	8.5	7.9	7.4
5.0	19.9	19.1	18.3	17.6	17.0	16.4	15.8	15.3	14.8	14.3	13.9	13.5	13.1	12.7	12.0	11.4	10.9	10.4	9.9	9.5	8.8	8.1	7.6
5.2	20.1	19.3	18.5	17.8	17.2	16.6	16.0	15.5	15.0	14.6	14.1	13.7	13.3	13.0	12.3	11.7	11.1	10.6	10.2	9.8	9.0	8.4	7.8
5.4	20.3	19.5	18.8	18.1	17.4	16.9	16.3	15.8	15.3	14.8	14.4	14.0	13.6	13.2	12.6	12.0	11.4	10.9	10.4	10.0	9.3	8.6	8.1
5.6	20.5	19.7	19.0	18.3	17.7	17.1	16.6	16.0	15.6	15.1	14.7	14.3	13.9	13.5	12.8	12.2	11.7	11.2	10.7	10.3	9.5	8.9	8.3
5.8	20.7	19.9	19.2	18.6	17.9	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.8	13.1	12.5	11.9	11.4	11.0	10.5	9.8	9.1	8.5
6.0	20.9	20.2	19.5	18.8	18.2	17.6	17.1	16.6	16.1	15.6	15.2	14.8	14.4	14.0	13.4	12.8	12.2	11.7	11.2	10.8	10.0	9.3	8.7
6.2	21.2	20.4	19.7	19.1	18.4	17.9	17.3	16.8	16.3	15.9	15.5	15.1	14.7	14.3	13.6	13.0	12.5	11.9	11.5	11.0	10.2	9.6	9.0
6.4	21.4	20.6	20.0	19.3	18.7	18.1	17.6	17.1	16.6	16.2	15.7	15.3	14.9	14.6	13.9	13.3	12.7	12.2	11.7	11.3	10.5	9.8	9.2
6.6	21.6	20.9	20.2	19.6	19.0	18.4	17.9	17.4	16.9	16.4	16.0	15.6	15.2	14.8	14.2	13.5	13.0	12.4	12.0	11.5	10.7	10.0	9.4
6.8	21.9	21.1	20.5	19.8	19.2	18.7	18.1	17.6	17.1	16.7	16.3	15.9	15.5	15.1	14.4	13.8	13.2	12.7	12.2	11.8	10.9	10.2	9.6
7.0	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.9	17.4	17.0	16.5	16.1	15.7	15.4	14.7	14.1	13.5	12.9	12.5	12.0	11.2	10.5	9.8
7.2	22.3	21.6	21.0	20.3	19.7	19.2	18.6	18.1	17.7	17.2	16.8	16.4	16.0	15.6	14.9	14.3	13.7	13.2	12.7	12.2	11.4	10.7	10.1
7.4	22.6	21.9	21.2	20.6	20.0	19.4	18.9	18.4	17.9	17.5	17.1	16.7	16.3	15.9	15.2	14.6	14.0	13.4	12.9	12.5	11.6	10.9	10.3
7.6	22.8	22.1	21.5	20.8	20.3	19.7	19.2	18.7	18.2	17.8	17.3	16.9	16.5	16.2	15.5	14.8	14.2	13.7	13.2	12.7	11.9	11.1	10.5
7.8	23.1	22.4	21.7	21.1	20.5	20.0	19.4	18.9	18.5	18.0	17.6	17.2	16.8	16.4	15.7	15.1	14.5	13.9	13.4	13.0	12.1	11.4	10.7
8.0	23.3	22.6	22.0	21.4	20.8	20.2	19.7	19.2	18.7	18.3	17.8	17.4	17.0	16.7	16.0	15.3	14.7	14.2	13.7	13.2	12.3	11.6	10.9
8.2	23.6	22.9	22.2	21.6	21.0	20.5	20.0	19.5	19.0	18.5	18.1	17.7	17.3	16.9	16.2	15.6	15.0	14.4	13.9	13.4	12.6	11.8	11.1
8.4	23.8	23.1	22.5	21.9	21.3	20.7	20.2	19.7	19.3	18.8	18.4	18.0	17.6	17.2	16.5	15.8	15.2	14.7	14.2	13.7	12.8	12.0	11.3
8.6	24.1	23.4	22.8	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.4	16.7	16.1	15.5	14.9	14.4	13.9	13.0	12.2	11.6
8.8	24.3	23.7	23.0	22.4	21.8	21.3	20.7	20.2	19.8	19.3	18.9	18.5	18.1	17.7	17.0	16.3	15.7	15.2	14.6	14.1	13.2	12.5	11.8
9.0	24.6	23.9	23.3	22.7	22.1	21.5	21.0	20.5	20.0	19.6	19.1	18.7	18.3	18.0	17.2	16.6	16.0	15.4	14.9	14.4	13.5	12.7	12.0
9.2	24.8	24.2	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.8	19.4	19.0	18.6	18.2	17.5	16.8	16.2	15.6	15.1	14.6	13.7	12.9	12.2
9.4	25.1	24.4	23.8	23.2	22.6	22.0	21.5	21.0	20.5	20.1	19.7	19.2	18.8	18.5	17.7	17.1	16.4	15.9	15.3	14.8	13.9	13.1	12.4
9.6	25.4	24.7	24.0	23.4	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.0	17.3	16.7	16.1	15.6	15.1	14.1	13.3	12.6
9.8	25.6	24.9	24.3	23.7	23.1	22.6	22.0	21.5	21.1	20.6	20.2	19.7	19.3	19.0	18.2	17.6	16.9	16.3	15.8	15.3	14.4	13.5	12.8
10.0	25.9	25.2	24.6	23.9	23.4	22.8	22.3	21.8	21.3	20.9	20.4	20.0	19.6	19.2	18.5	17.8	17.2	16.6	16.0	15.5	14.6	13.8	13.0
10.5	26.5	25.8	25.2	24.6	24.0	23.5	22.9	22.4	22.0	21.5	21.0	20.6	20.2	19.8	19.1	18.4	17.8	17.2	16.6	16.1	15.1	14.3	13.5
11.0	27.1	26.5	25.8	25.2	24.7	24.1	23.6	23.1	22.6	22.1	21.7	21.2	20.8	20.4	19.7	19.0	18.4	17.7	17.2	16.6	15.7	14.8	14.0
11.5	27.8	27.1	26.5	25.9	25.3	24.7	24.2	23.7	23.2	22.7	22.3	21.9	21.5	21.1	20.3	19.6	18.9	18.3	17.7	17.2	16.2	15.3	14.5
12.0	28.4	27.7	27.1	26.5	25.9	25.4	24.8	24.3	23.8	23.4	22.9	22.5	22.1	21.7	20.9	20.2	19.5	18.9	18.3	17.8	16.8	15.9	15.1
12.5	29.0	28.4	27.7	27.1	26.6	26.0	25.5	25.0	24.5	24.0	23.5	23.1	22.7	22.3	21.5	20.8	20.1	19.5	18.9	18.3	17.3	16.4	15.6
13.0	29.7	29.0	28.4	27.8	27.2	26.6	26.1	25.6	25.1	24.6	24.1	23.7	23.3	22.9	22.1	21.3	20.7	20.0	19.4	18.9	17.8	16.9	16.0
13.5	30.3	29.6	29.0	28.4	27.8	27.2	26.7	26.2	25.7	25.2	24.7	24.3	23.9	23.5	22.7	21.9	21.2	20.6	20.0	19.4	18.3	17.4	16.5
14.0	30.9	30.3	29.6	29.0	28.4	27.9	27.3	26.8	26.3	25.8	25.3	24.9	24.5	24.0	23.2	22.5	21.8	21.1	20.5	19.9	18.9	17.9	17.0
14.5	31.6	30.9	30.3	29.6	29.0	28.5	27.9	27.4	26.9	26.4	25.9	25.5	25.1	24.6	23.8	23.1	22.4	21.7	21.1	20.5	19.4	18.4	17.5
15.0	32.2	31.5	30.9	30.3	29.7	29.1	28.5	28.0	27.5	27.0	26.5	26.1	25.6	25.2	24.4	23.6	22.9	22.2	21.6	21.0	19.9	18.9	18.0
15.5	32.8	32.1	31.5	30.9	30.3	29.7	29.1	28.6	28.1	27.6	27.1	26.7	26.2	25.8	25.0	24.2	23.5	22.8	22.2	21.5	20.4	19.4	18.5
16.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.2	28.7	28.2	27.7	27.3	26.8	26.4	25.5	24.8	24.0	23.3	22.7	22.1	20.9	19.9	19.0
16.5	34.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.3	28.8	28.3	27.8	27.4	26.9	26.1	25.3	24.6	23.9	23.2	22.6	21.4	20.4	19.5
17.0	34.7	34.0	33.3	32.7	32.1	31.5	30.9	30.4	29.9	29.4	28.9	28.4	28.0	27.5	26.7	25.9	25.1	24.4	23.8	23.1	22.0	20.9	19.9
17.5	35.3	34.6	33.9	33.3	32.7	32.1	31.5	31.0	30.5	30.0	29.5	29.0	28.5	28.1	27.2	26.4	25.7	25.0	24.3	23.6	22.5	21.4	20.4
18.0	35.9	35.2	34.5	33.9	33.3	32.7	32.1	31.6	31.1	30.5	30.0	29.6	29.1	28.6	27.8	27.0	26.2	25.5	24.8	24.2	23.0	21.9	20.9
18.5	36.5	35.8	35.1	34.5	33.9	33.3	32.7	32.2	31.6	31.1	30.6	30.1	29.7	29.2	28.3	27.5	26.8	26.0	25.3	24.7	23.5	22.4	21.4
19.0	37.1	36.4	35.7	35.1	34.5	33.9	33.3	32.8	32.2	31.7	31.2	30.7	30.2	29.8	28.9	28.1	27.3	26.5	25.8	25.2	24.0	22.8	21.8
19.5	37.7	37.0	36.3	35.7	35.1	34.5	33.9	33.3	32.8	32.3	31.8	31.3	30.8	30.3	29.4	28.6	27.8	27.1	26.4	25.7	24.5	23.3	22.3
20.0	38.3	37.6	36.9	36.3	35.7	35.1	34.5	33.9	33.4	32.8	32.3	31.8	31.3	30.9	30.0	29.1	28.4	27.6	26.9	26.2	24.9	23.8	22.8
21.0	39.5	38.8	38.1	37.4	36.8	36.2	35.6	35.1	34.5	34.0	33.4	32.9	32.5	32.0	31.1	30.2	29.4	28.6	27.9	27.2	25.9	24.8	23.7
22.0	40.7	40.0	39.3	38.6	38.0	37.4	36.8	36.2	35.6	35.1	34.6	34.1	33.6	33.1	32.2	31.3	30.5	29.7	28.9	28.2	26.9	25.7	24.6

~~Table I-4B: Basic Energy Use (BEU) - Storage Electric Heater [no interpolation]~~

~~Adjusted Load~~	~~Energy Factor~~																						
	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
3.0	22.4	21.1	20.0	19.0	18.1	17.2	16.5	15.8	15.2	14.6	14.0	13.5	13.0	12.6	12.2	11.8	11.5	11.1	10.8	10.5	10.2	9.9	9.7
3.2	23.0	21.8	20.7	19.7	18.8	18.0	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.1	11.8	11.5	11.1	10.8	10.6	10.3
3.4	23.6	22.4	21.3	20.4	19.5	18.7	17.9	17.2	16.6	16.0	15.4	14.9	14.4	14.0	13.6	13.2	12.8	12.4	12.1	11.8	11.5	11.2	10.9
3.6	24.2	23.1	22.0	21.1	20.2	19.4	18.6	17.9	17.3	16.7	16.1	15.6	15.1	14.7	14.2	13.8	13.5	13.1	12.7	12.4	12.1	11.8	11.5
3.8	24.8	23.7	22.7	21.7	20.9	20.1	19.3	18.6	18.0	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.7	13.4	13.1	12.7	12.4	12.1
4.0	25.5	24.4	23.3	22.4	21.6	20.8	20.0	19.3	18.7	18.1	17.5	17.0	16.5	16.0	15.6	15.2	14.8	14.4	14.0	13.7	13.4	13.1	12.8
4.2	26.1	25.0	24.0	23.1	22.2	21.4	20.7	20.0	19.4	18.8	18.2	17.7	17.2	16.7	16.3	15.8	15.4	15.0	14.7	14.3	14.0	13.7	13.4
4.4	26.7	25.6	24.7	23.8	22.9	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.8	17.4	16.9	16.5	16.1	15.7	15.3	15.0	14.6	14.3	14.0
4.6	27.3	26.3	25.3	24.4	23.6	22.8	22.1	21.4	20.7	20.1	19.6	19.0	18.5	18.0	17.6	17.1	16.7	16.3	15.9	15.6	15.2	14.9	14.6
4.8	28.0	26.9	26.0	25.1	24.3	23.5	22.7	22.1	21.4	20.8	20.2	19.7	19.2	18.7	18.2	17.8	17.4	17.0	16.6	16.2	15.9	15.5	15.2
5.0	28.6	27.6	26.6	25.7	24.9	24.1	23.4	22.7	22.1	21.5	20.9	20.4	19.8	19.3	18.9	18.4	18.0	17.6	17.2	16.8	16.5	16.1	15.8
5.2	29.2	28.2	27.3	26.4	25.6	24.8	24.1	23.4	22.7	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.5	17.1	16.7	16.4
5.4	29.8	28.8	27.9	27.0	26.2	25.5	24.7	24.1	23.4	22.8	22.2	21.7	21.1	20.6	20.2	19.7	19.3	18.9	18.5	18.1	17.7	17.4	17.0
5.6	30.4	29.5	28.5	27.7	26.9	26.1	25.4	24.7	24.1	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.3	18.0	17.6
5.8	31.0	30.1	29.2	28.3	27.5	26.8	26.0	25.4	24.7	24.1	23.5	23.0	22.4	21.9	21.4	21.0	20.5	20.1	19.7	19.3	18.9	18.6	18.2
6.0	31.6	30.7	29.8	29.0	28.2	27.4	26.7	26.0	25.4	24.7	24.2	23.6	23.1	22.6	22.1	21.6	21.2	20.7	20.3	19.9	19.5	19.2	18.8
6.2	32.3	31.3	30.4	29.6	28.8	28.0	27.3	26.7	26.0	25.4	24.8	24.2	23.7	23.2	22.7	22.2	21.8	21.4	20.9	20.5	20.2	19.8	19.4
6.4	32.9	31.9	31.1	30.2	29.4	28.7	28.0	27.3	26.6	26.0	25.4	24.9	24.3	23.8	23.3	22.9	22.4	22.0	21.6	21.2	20.8	20.4	20.0
6.6	33.5	32.5	31.7	30.8	30.1	29.3	28.6	27.9	27.3	26.7	26.1	25.5	25.0	24.5	24.0	23.5	23.0	22.6	22.2	21.8	21.4	21.0	20.6
6.8	34.1	33.2	32.3	31.5	30.7	29.9	29.2	28.6	27.9	27.3	26.7	26.2	25.6	25.1	24.6	24.1	23.7	23.2	22.8	22.4	22.0	21.6	21.2
7.0	34.7	33.8	32.9	32.1	31.3	30.6	29.9	29.2	28.6	27.9	27.3	26.8	26.2	25.7	25.2	24.7	24.3	23.8	23.4	23.0	22.6	22.2	21.8
7.2	35.3	34.4	33.5	32.7	31.9	31.2	30.5	29.8	29.2	28.6	28.0	27.4	26.9	26.3	25.8	25.4	24.9	24.4	24.0	23.6	23.2	22.8	22.4
7.4	35.9	35.0	34.1	33.3	32.6	31.8	31.1	30.5	29.8	29.2	28.6	28.0	27.5	27.0	26.5	26.0	25.5	25.1	24.6	24.2	23.8	23.4	23.0
7.6	36.5	35.6	34.7	33.9	33.2	32.4	31.7	31.1	30.4	29.8	29.2	28.7	28.1	27.6	27.1	26.6	26.1	25.7	25.2	24.8	24.4	24.0	23.6
7.8	37.0	36.2	35.3	34.5	33.8	33.1	32.4	31.7	31.1	30.4	29.8	29.3	28.7	28.2	27.7	27.2	26.7	26.3	25.8	25.4	25.0	24.6	24.2
8.0	37.6	36.8	35.9	35.2	34.4	33.7	33.0	32.3	31.7	31.1	30.5	29.9	29.4	28.8	28.3	27.8	27.3	26.9	26.4	26.0	25.6	25.2	24.8
8.2	38.2	37.4	36.5	35.8	35.0	34.3	33.6	32.9	32.3	31.7	31.1	30.5	30.0	29.4	28.9	28.4	28.0	27.5	27.0	26.6	26.2	25.8	25.4
8.4	38.8	37.9	37.1	36.4	35.6	34.9	34.2	33.5	32.9	32.3	31.7	31.1	30.6	30.0	29.5	29.0	28.6	28.1	27.7	27.2	26.8	26.4	26.0
8.6	39.4	38.5	37.7	37.0	36.2	35.5	34.8	34.2	33.5	32.9	32.3	31.7	31.2	30.7	30.1	29.7	29.2	28.7	28.3	27.8	27.4	27.0	26.6
8.8	40.0	39.1	38.3	37.6	36.8	36.1	35.4	34.8	34.1	33.5	32.9	32.4	31.8	31.3	30.8	30.3	29.8	29.3	28.9	28.4	28.0	27.6	27.2
9.0	40.5	39.7	38.9	38.1	37.4	36.7	36.0	35.4	34.7	34.1	33.5	33.0	32.4	31.9	31.4	30.9	30.4	29.9	29.5	29.0	28.6	28.2	27.8
9.2	41.1	40.3	39.5	38.7	38.0	37.3	36.6	36.0	35.3	34.7	34.1	33.6	33.0	32.5	32.0	31.5	31.0	30.5	30.1	29.6	29.2	28.8	28.4
9.4	41.7	40.9	40.1	39.3	38.6	37.9	37.2	36.6	35.9	35.3	34.7	34.2	33.6	33.1	32.6	32.1	31.6	31.1	30.7	30.2	29.8	29.4	29.0
9.6	42.3	41.4	40.7	39.9	39.2	38.5	37.8	37.2	36.5	35.9	35.3	34.8	34.2	33.7	33.2	32.7	32.2	31.7	31.3	30.8	30.4	30.0	29.5
9.8	42.8	42.0	41.2	40.5	39.8	39.1	38.4	37.8	37.1	36.5	35.9	35.4	34.8	34.3	33.8	33.3	32.8	32.3	31.9	31.4	31.0	30.5	30.1
10.0	43.4	42.6	41.8	41.1	40.4	39.7	39.0	38.4	37.7	37.1	36.5	36.0	35.4	34.9	34.4	33.9	33.4	32.9	32.4	32.0	31.6	31.1	30.7
10.5	44.8	44.0	43.3	42.5	41.8	41.1	40.5	39.8	39.2	38.6	38.0	37.5	36.9	36.4	35.9	35.4	34.9	34.4	33.9	33.5	33.0	32.6	32.2
11.0	46.2	45.4	44.7	44.0	43.3	42.6	41.9	41.3	40.7	40.1	39.5	39.0	38.4	37.9	37.4	36.8	36.4	35.9	35.4	35.0	34.5	34.1	33.7
11.5	47.6	46.8	46.1	45.4	44.7	44.0	43.4	42.8	42.2	41.6	41.0	40.4	39.9	39.3	38.8	38.3	37.8	37.4	36.9	36.4	36.0	35.6	35.1
12.0	49.0	48.2	47.5	46.8	46.1	45.5	44.8	44.2	43.6	43.0	42.5	41.9	41.3	40.8	40.3	39.8	39.3	38.8	38.4	37.9	37.5	37.0	36.6
12.5	50.3	49.6	48.9	48.2	47.6	46.9	46.3	45.7	45.1	44.5	43.9	43.4	42.8	42.3	41.8	41.3	40.8	40.3	39.8	39.4	38.9	38.5	38.1
13.0	51.7	51.0	50.3	49.6	49.0	48.3	47.7	47.1	46.5	45.9	45.4	44.8	44.3	43.7	43.2	42.7	42.2	41.8	41.3	40.8	40.4	40.0	39.5
13.5	53.1	52.4	51.7	51.0	50.4	49.7	49.1	48.5	47.9	47.3	46.8	46.2	45.7	45.2	44.7	44.2	43.7	43.2	42.8	42.3	41.8	41.4	41.0
14.0	54.4	53.7	53.0	52.4	51.7	51.1	50.5	49.9	49.3	48.8	48.2	47.7	47.2	46.6	46.1	45.6	45.1	44.7	44.2	43.8	43.3	42.9	42.4
14.5	55.7	55.1	54.4	53.8	53.1	52.5	51.9	51.3	50.8	50.2	49.6	49.1	48.6	48.1	47.6	47.1	46.6	46.1	45.7	45.2	44.8	44.3	43.9
15.0	57.1	56.4	55.7	55.1	54.5	53.9	53.3	52.7	52.2	51.6	51.1	50.5	50.0	49.5	49.0	48.5	48.0	47.6	47.1	46.7	46.2	45.8	45.3
15.5	58.4	57.7	57.1	56.5	55.9	55.3	54.7	54.1	53.6	53.0	52.5	52.0	51.4	50.9	50.4	50.0	49.5	49.0	48.5	48.1	47.7	47.2	46.8
16.0	59.7	59.1	58.4	57.8	57.2	56.6	56.1	55.5	54.9	54.4	53.9	53.4	52.9	52.4	51.9	51.4	50.9	50.4	50.0	49.5	49.1	48.7	48.2
16.5	61.0	60.4	59.8	59.2	58.6	58.0	57.4	56.9	56.3	55.8	55.3	54.8	54.3	53.8	53.3	52.8	52.3	51.9	51.4	51.0	50.5	50.1	49.7
17.0	62.3	61.7	61.1	60.5	59.9	59.4	58.8	58.3	57.7	57.2	56.7	56.2	55.7	55.2	54.7	54.2	53.8	53.3	52.9	52.4	52.0	51.6	51.1
17.5	63.6	63.0	62.4	61.8	61.3	60.7	60.2	59.6	59.1	58.6	58.1	57.6	57.1	56.6	56.1	55.6	55.2	54.7	54.3	53.9	53.4	53.0	52.6
18.0	64.9	64.3	63.7	63.1	62.6	62.0	61.5	61.0	60.5	59.9	59.4	59.0	58.5	58.0	57.5	57.1	56.6	56.2	55.7	55.3	54.9	54.4	54.0
18.5	66.1	65.6	65.0	64.5	63.9	63.4	62.8	62.3	61.8	61.3	60.8	60.3	59.9	59.4	58.9	58.5	58.0	57.6	57.1	56.7	56.3	55.9	55.5
19.0	67.4	66.9	66.3	65.8	65.2	64.7	64.2	63.7	63.2	62.7	62.2	61.7	61.2	60.8	60.3	59.9	59.4	59.0	58.6	58.1	57.7	57.3	56.9
19.5	68.7	68.1	67.6	67.1	66.5	66.0	65.5	65.0	64.5	64.0	63.6	63.1	62.6	62.2	61.7	61.3	60.8	60.4	60.0	59.6	59.2	58.7	58.3
20.0	70.0	69.4	68.9	68.4	67.9	67.3	66.8	66.4	65.9	65.4	64.9	64.5	64.0	63.6	63.1	62.7	62.3	61.8	61.4	61.0	60.6	60.2	59.8
21.0	72.5	71.9	71.4	70.9	70.5	70.0	69.5	69.0	68.6	68.1	67.6	67.2	66.8	66.3	65.9	65.5	65.1	64.6	64.2	63.8	63.4	63.0	62.7
22.0	74.9	74.5	74.0	73.5	73.0	72.6	72.1	71.7	71.2	70.8	70.3	69.9	69.5	69.1	68.7	68.2	67.8	67.4	67.1	66.7	66.3	65.9	65.5

~~Adjusted Load~~	~~Energy Factor~~																				
	~~1.8~~	~~1.9~~	~~2.0~~	~~2.1~~	~~2.2~~	~~2.3~~	~~2.4~~	~~2.5~~	~~2.6~~	~~2.7~~	~~2.8~~	~~2.9~~	~~3.0~~	~~3.1~~	~~3.2~~	~~3.3~~	~~3.4~~	~~3.5~~	~~3.6~~	~~3.7~~	~~3.8~~
~~6.0~~	~~14.1~~	~~13.5~~	~~13.0~~	~~12.6~~	~~12.1~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.7~~	~~9.5~~	~~9.2~~	~~9.0~~	~~8.7~~	~~8.5~~	~~8.3~~	~~8.1~~	~~7.9~~	~~7.8~~
~~6.2~~	~~14.4~~	~~13.8~~	~~13.3~~	~~12.8~~	~~12.3~~	~~11.9~~	~~11.5~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.6~~	~~9.3~~	~~9.1~~	~~8.9~~	~~8.7~~	~~8.4~~	~~8.2~~	~~8.0~~	~~7.9~~
~~6.4~~	~~14.7~~	~~14.1~~	~~13.5~~	~~13.0~~	~~12.5~~	~~12.1~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.7~~	~~9.5~~	~~9.2~~	~~9.0~~	~~8.8~~	~~8.6~~	~~8.3~~	~~8.2~~	~~8.0~~
~~6.6~~	~~14.9~~	~~14.3~~	~~13.8~~	~~13.2~~	~~12.8~~	~~12.3~~	~~11.9~~	~~11.5~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.1~~	~~8.9~~	~~8.7~~	~~8.5~~	~~8.3~~	~~8.1~~
~~6.8~~	~~15.2~~	~~14.6~~	~~14.0~~	~~13.5~~	~~13.0~~	~~12.5~~	~~12.1~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.8~~	~~9.5~~	~~9.3~~	~~9.0~~	~~8.8~~	~~8.6~~	~~8.4~~	~~8.2~~
~~7.0~~	~~15.5~~	~~14.8~~	~~14.2~~	~~13.7~~	~~13.2~~	~~12.7~~	~~12.3~~	~~11.9~~	~~11.5~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.1~~	~~8.9~~	~~8.7~~	~~8.5~~	~~8.3~~
~~7.2~~	~~15.8~~	~~15.1~~	~~14.5~~	~~13.9~~	~~13.4~~	~~12.9~~	~~12.5~~	~~12.1~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.8~~	~~9.5~~	~~9.3~~	~~9.0~~	~~8.8~~	~~8.6~~	~~8.4~~
~~7.4~~	~~16.0~~	~~15.4~~	~~14.7~~	~~14.2~~	~~13.6~~	~~13.1~~	~~12.7~~	~~12.2~~	~~11.8~~	~~11.5~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.1~~	~~8.9~~	~~8.7~~	~~8.5~~
~~7.6~~	~~16.3~~	~~15.6~~	~~15.0~~	~~14.4~~	~~13.8~~	~~13.3~~	~~12.9~~	~~12.4~~	~~12.0~~	~~11.6~~	~~11.3~~	~~10.9~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.8~~	~~9.5~~	~~9.3~~	~~9.0~~	~~8.8~~	~~8.6~~
~~7.8~~	~~16.6~~	~~15.9~~	~~15.2~~	~~14.6~~	~~14.0~~	~~13.5~~	~~13.0~~	~~12.6~~	~~12.2~~	~~11.8~~	~~11.4~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.2~~	~~8.9~~	~~8.7~~
~~8.0~~	~~16.8~~	~~16.1~~	~~15.4~~	~~14.8~~	~~14.3~~	~~13.7~~	~~13.2~~	~~12.8~~	~~12.4~~	~~12.0~~	~~11.6~~	~~11.2~~	~~10.9~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.8~~	~~9.5~~	~~9.3~~	~~9.0~~	~~8.8~~
~~8.2~~	~~17.1~~	~~16.4~~	~~15.7~~	~~15.0~~	~~14.5~~	~~13.9~~	~~13.4~~	~~13.0~~	~~12.5~~	~~12.1~~	~~11.7~~	~~11.4~~	~~11.0~~	~~10.7~~	~~10.4~~	~~10.1~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.2~~	~~8.9~~
~~8.4~~	~~17.4~~	~~16.6~~	~~15.9~~	~~15.3~~	~~14.7~~	~~14.1~~	~~13.6~~	~~13.1~~	~~12.7~~	~~12.3~~	~~11.9~~	~~11.5~~	~~11.2~~	~~10.9~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.7~~	~~9.5~~	~~9.3~~	~~9.0~~
~~8.6~~	~~17.7~~	~~16.9~~	~~16.1~~	~~15.5~~	~~14.9~~	~~14.3~~	~~13.8~~	~~13.3~~	~~12.9~~	~~12.4~~	~~12.0~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.7~~	~~10.4~~	~~10.1~~	~~9.9~~	~~9.6~~	~~9.4~~	~~9.1~~
~~8.8~~	~~17.9~~	~~17.1~~	~~16.4~~	~~15.7~~	~~15.1~~	~~14.5~~	~~14.0~~	~~13.5~~	~~13.0~~	~~12.6~~	~~12.2~~	~~11.8~~	~~11.5~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~10.0~~	~~9.7~~	~~9.5~~	~~9.3~~
~~9.0~~	~~18.2~~	~~17.4~~	~~16.6~~	~~15.9~~	~~15.3~~	~~14.7~~	~~14.2~~	~~13.7~~	~~13.2~~	~~12.8~~	~~12.4~~	~~12.0~~	~~11.6~~	~~11.3~~	~~11.0~~	~~10.7~~	~~10.4~~	~~10.1~~	~~9.8~~	~~9.6~~	~~9.4~~
~~9.2~~	~~18.4~~	~~17.6~~	~~16.8~~	~~16.1~~	~~15.5~~	~~14.9~~	~~14.4~~	~~13.9~~	~~13.4~~	~~12.9~~	~~12.5~~	~~12.1~~	~~11.8~~	~~11.4~~	~~11.1~~	~~10.8~~	~~10.5~~	~~10.2~~	~~10.0~~	~~9.7~~	~~9.5~~
~~9.4~~	~~18.7~~	~~17.9~~	~~17.1~~	~~16.4~~	~~15.7~~	~~15.1~~	~~14.5~~	~~14.0~~	~~13.5~~	~~13.1~~	~~12.7~~	~~12.3~~	~~11.9~~	~~11.5~~	~~11.3~~	~~10.9~~	~~10.6~~	~~10.3~~	~~10.1~~	~~9.8~~	~~9.6~~
~~9.6~~	~~19.0~~	~~18.1~~	~~17.3~~	~~16.6~~	~~15.9~~	~~15.3~~	~~14.7~~	~~14.2~~	~~13.7~~	~~13.3~~	~~12.8~~	~~12.4~~	~~12.0~~	~~11.7~~	~~11.4~~	~~11.0~~	~~10.7~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.7~~
~~9.8~~	~~19.2~~	~~18.3~~	~~17.5~~	~~16.8~~	~~16.1~~	~~15.5~~	~~14.9~~	~~14.4~~	~~13.9~~	~~13.4~~	~~13.0~~	~~12.6~~	~~12.2~~	~~11.8~~	~~11.5~~	~~11.2~~	~~10.9~~	~~10.6~~	~~10.3~~	~~10.0~~	~~9.8~~
~~10.0~~	~~19.5~~	~~18.6~~	~~17.8~~	~~17.0~~	~~16.3~~	~~15.7~~	~~15.1~~	~~14.6~~	~~14.0~~	~~13.6~~	~~13.1~~	~~12.7~~	~~12.3~~	~~12.0~~	~~11.7~~	~~11.3~~	~~11.0~~	~~10.7~~	~~10.4~~	~~10.1~~	~~9.9~~
~~10.5~~	~~20.1~~	~~19.2~~	~~18.3~~	~~17.6~~	~~16.8~~	~~16.2~~	~~15.6~~	~~15.0~~	~~14.5~~	~~14.0~~	~~13.5~~	~~13.1~~	~~12.7~~	~~12.3~~	~~11.9~~	~~11.6~~	~~11.3~~	~~11.0~~	~~10.7~~	~~10.4~~	~~10.2~~
~~11.0~~	~~20.8~~	~~19.8~~	~~18.9~~	~~18.1~~	~~17.3~~	~~16.7~~	~~16.0~~	~~15.4~~	~~14.9~~	~~14.4~~	~~13.9~~	~~13.4~~	~~13.0~~	~~12.6~~	~~12.3~~	~~11.9~~	~~11.6~~	~~11.3~~	~~11.0~~	~~10.7~~	~~10.4~~
~~11.5~~	~~21.4~~	~~20.4~~	~~19.5~~	~~18.6~~	~~17.8~~	~~17.1~~	~~16.5~~	~~15.9~~	~~15.3~~	~~14.8~~	~~14.3~~	~~13.8~~	~~13.4~~	~~13.0~~	~~12.6~~	~~12.2~~	~~11.9~~	~~11.6~~	~~11.3~~	~~11.0~~	~~10.7~~
~~12.0~~	~~22.1~~	~~21.0~~	~~20.0~~	~~19.1~~	~~18.3~~	~~17.6~~	~~16.9~~	~~16.3~~	~~15.7~~	~~15.1~~	~~14.6~~	~~14.2~~	~~13.7~~	~~13.3~~	~~12.9~~	~~12.5~~	~~12.2~~	~~11.9~~	~~11.5~~	~~11.2~~	~~11.0~~
~~12.5~~	~~22.7~~	~~21.6~~	~~20.6~~	~~19.7~~	~~18.8~~	~~18.1~~	~~17.4~~	~~16.7~~	~~16.1~~	~~15.5~~	~~15.0~~	~~14.5~~	~~14.1~~	~~13.6~~	~~13.2~~	~~12.8~~	~~12.5~~	~~12.1~~	~~11.8~~	~~11.5~~	~~11.2~~
~~13.0~~	~~23.3~~	~~22.2~~	~~21.1~~	~~20.2~~	~~19.3~~	~~18.5~~	~~17.8~~	~~17.1~~	~~16.5~~	~~15.9~~	~~15.4~~	~~14.9~~	~~14.4~~	~~14.0~~	~~13.5~~	~~13.1~~	~~12.8~~	~~12.4~~	~~12.1~~	~~11.8~~	~~11.5~~
~~13.5~~	~~23.9~~	~~22.7~~	~~21.7~~	~~20.7~~	~~19.8~~	~~19.0~~	~~18.2~~	~~17.6~~	~~16.9~~	~~16.3~~	~~15.8~~	~~15.2~~	~~14.7~~	~~14.3~~	~~13.9~~	~~13.5~~	~~13.1~~	~~12.7~~	~~12.4~~	~~12.0~~	~~11.7~~
~~14.0~~	~~24.5~~	~~23.3~~	~~22.2~~	~~21.2~~	~~20.3~~	~~19.5~~	~~18.7~~	~~18.0~~	~~17.3~~	~~16.7~~	~~16.1~~	~~15.6~~	~~15.1~~	~~14.6~~	~~14.2~~	~~13.8~~	~~13.4~~	~~13.0~~	~~12.6~~	~~12.3~~	~~12.0~~
~~14.5~~	~~25.2~~	~~23.9~~	~~22.8~~	~~21.7~~	~~20.8~~	~~19.9~~	~~19.1~~	~~18.4~~	~~17.7~~	~~17.1~~	~~16.5~~	~~15.9~~	~~15.4~~	~~14.9~~	~~14.5~~	~~14.1~~	~~13.7~~	~~13.3~~	~~12.9~~	~~12.6~~	~~12.3~~
~~15.0~~	~~25.8~~	~~24.5~~	~~23.3~~	~~22.2~~	~~21.3~~	~~20.4~~	~~19.6~~	~~18.8~~	~~18.1~~	~~17.4~~	~~16.8~~	~~16.3~~	~~15.8~~	~~15.3~~	~~14.8~~	~~14.4~~	~~13.9~~	~~13.6~~	~~13.2~~	~~12.8~~	~~12.5~~
~~15.5~~	~~26.4~~	~~25.0~~	~~23.8~~	~~22.7~~	~~21.7~~	~~20.8~~	~~20.0~~	~~19.2~~	~~18.5~~	~~17.8~~	~~17.2~~	~~16.6~~	~~16.1~~	~~15.6~~	~~15.1~~	~~14.7~~	~~14.2~~	~~13.8~~	~~13.5~~	~~13.1~~	~~12.8~~
~~16.0~~	~~27.0~~	~~25.6~~	~~24.4~~	~~23.2~~	~~22.2~~	~~21.3~~	~~20.4~~	~~19.6~~	~~18.9~~	~~18.2~~	~~17.6~~	~~17.0~~	~~16.4~~	~~15.9~~	~~15.4~~	~~15.0~~	~~14.5~~	~~14.1~~	~~13.7~~	~~13.4~~	~~13.0~~
~~16.5~~	~~27.6~~	~~26.2~~	~~24.9~~	~~23.7~~	~~22.7~~	~~21.7~~	~~20.8~~	~~20.0~~	~~19.3~~	~~18.6~~	~~17.9~~	~~17.3~~	~~16.7~~	~~16.2~~	~~15.7~~	~~15.2~~	~~14.8~~	~~14.4~~	~~14.0~~	~~13.6~~	~~13.3~~
~~17.0~~	~~28.2~~	~~26.7~~	~~25.4~~	~~24.2~~	~~23.2~~	~~22.2~~	~~21.3~~	~~20.4~~	~~19.7~~	~~18.9~~	~~18.3~~	~~17.7~~	~~17.1~~	~~16.5~~	~~16.0~~	~~15.5~~	~~15.1~~	~~14.7~~	~~14.3~~	~~13.9~~	~~13.5~~
~~17.5~~	~~28.8~~	~~27.3~~	~~25.9~~	~~24.7~~	~~23.6~~	~~22.6~~	~~21.7~~	~~20.8~~	~~20.0~~	~~19.3~~	~~18.6~~	~~18.0~~	~~17.4~~	~~16.8~~	~~16.3~~	~~15.8~~	~~15.4~~	~~14.9~~	~~14.5~~	~~14.1~~	~~13.8~~
~~18.0~~	~~29.4~~	~~27.8~~	~~26.5~~	~~25.2~~	~~24.1~~	~~23.1~~	~~22.1~~	~~21.2~~	~~20.4~~	~~19.7~~	~~19.0~~	~~18.3~~	~~17.7~~	~~17.2~~	~~16.6~~	~~16.1~~	~~15.7~~	~~15.2~~	~~14.8~~	~~14.4~~	~~14.0~~
~~18.5~~	~~29.9~~	~~28.4~~	~~27.0~~	~~25.7~~	~~24.5~~	~~23.5~~	~~22.5~~	~~21.6~~	~~20.8~~	~~20.0~~	~~19.3~~	~~18.7~~	~~18.0~~	~~17.5~~	~~16.9~~	~~16.4~~	~~15.9~~	~~15.5~~	~~15.1~~	~~14.7~~	~~14.3~~
~~19.0~~	~~30.5~~	~~28.9~~	~~27.5~~	~~26.2~~	~~25.0~~	~~23.9~~	~~23.3~~	~~22.0~~	~~21.2~~	~~20.4~~	~~19.7~~	~~19.0~~	~~18.4~~	~~17.8~~	~~17.2~~	~~16.7~~	~~16.2~~	~~15.8~~	~~15.3~~	~~14.9~~	~~14.5~~
~~19.5~~	~~31.1~~	~~29.5~~	~~28.0~~	~~26.7~~	~~25.5~~	~~24.4~~	~~23.3~~	~~22.4~~	~~21.6~~	~~20.8~~	~~20.0~~	~~19.3~~	~~18.7~~	~~18.1~~	~~17.5~~	~~17.0~~	~~16.5~~	~~16.0~~	~~15.6~~	~~15.2~~	~~14.8~~
~~20.0~~	~~31.7~~	~~30.0~~	~~28.5~~	~~27.2~~	~~25.9~~	~~24.8~~	~~23.8~~	~~22.8~~	~~21.9~~	~~21.1~~	~~20.4~~	~~19.7~~	~~19.0~~	~~18.4~~	~~17.8~~	~~17.3~~	~~16.8~~	~~16.3~~	~~15.8~~	~~15.4~~	~~15.0~~
~~21.0~~	~~32.8~~	~~31.1~~	~~29.5~~	~~28.1~~	~~26.8~~	~~25.7~~	~~24.6~~	~~23.6~~	~~22.7~~	~~21.8~~	~~21.1~~	~~20.3~~	~~19.6~~	~~19.0~~	~~18.4~~	~~17.8~~	~~17.3~~	~~16.8~~	~~16.4~~	~~15.9~~	~~15.5~~
~~22.0~~	~~34.0~~	~~32.2~~	~~30.5~~	~~29.1~~	~~27.7~~	~~26.5~~	~~25.4~~	~~24.4~~	~~23.4~~	~~22.5~~	~~21.7~~	~~21.0~~	~~20.3~~	~~19.6~~	~~19.0~~	~~18.4~~	~~17.9~~	~~17.4~~	~~16.9~~	~~16.4~~	~~16.0~~

~~Climate Zone~~	~~Factor~~
~~1.14~~	~~1.04~~
~~2, 3~~	~~0.99~~
~~4, 5, 12~~	~~1.07~~
~~6-11, 13, 15~~	~~0.92~~
~~16~~	~~1.50~~

~~Basic Energy Use x CZ Factor. = BEU to Line 2a, DHW-1~~

~~Instructions: Multiply Basic Energy Use by appropriate Climate Zone Factor from table.~~ ~~**Do not interpolate.**~~

ACM RH-2005

Appendix RH – High Quality Insulation Installation Procedures

RH1. Purpose and Scope

ACM RH-2005 is a procedure for verifying the quality of insulation installation in low-rise residential buildings. A compliance credit is offered when this procedure is followed by the insulation installer and a qualified HERS rater. The procedure and credit applies to wood framed construction with wall stud cavities, ceilings, and roof assemblies insulated with mineral fiber or cellulose insulation in low-rise residential buildings.

RH2. Terminology

Air Barrier — An air barrier is needed in all thermal envelope assemblies to prevent air movement. Insulation, other than foam, is not designed to stop air movement. For insulation installed horizontally, such as in an attic, the insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-value. A wall or ceiling covering that has multiple leakage sites (such as 1 x 6 toung and grove board ceilings) can not serve as an air barrier.

Air-tight — Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement can move unwanted heat and moisture through or into the assembly. For these procedures air-tight shall be defined as an assembly or air barrier with all openings greater than 1/8 inch caulked, or sealed with expansive or minimally expansive foam.

Excessive Compression — Batt insulation may be compressed up to 50% at obstructions such as plumbing vents and in non-standard cavities, but compression of more than 50% in any dimension is excessive and shall not be allowed. Where obstructions would cause the insulation to be compressed greater than 50% insulation shall be cut to fit around the obstruction.

Delaminated — Batts are often split or delaminated to fit around an obstruction. For example when an electrical wire runs through a wall cavity the insulation must still fill the area both in front of the wire and the area behind the wire. This is typically accomplished by delaminating the batt from one end and placing one side of the batt behind the wire and the other in front of the wire. The location of the delamination must coincide with the location of the obstruction. For example if the wire is one third of the distance from the front of the cavity the batt should be delaminated so that two thirds of the batt goes behind the wire and one third in front of the wire.

Draft Stops — Draft stops are installed to prevent air movement between wall cavities, other interstitial cavities - and the attic. They are typically constructed of dimensional lumber blocking, drywall or plywood. Draft stops become part of the attic air barrier and shall be air-tight. Fire blocks constructed of porous insulation materials cannot serve as draft stops since they are not air-tight.

Friction Fit — Friction fit batts are commonly used. Friction fit batts have enough side-to-side frictional force to hold the batt in place without any other means of attachment.

Gaps — A gap is an uninsulated area at the edge of or between batts. Gaps in insulation are avoidable and are not permitted.

Hard Covers — Hard covers shall be installed above areas where there is a drop ceiling. For example a home with 10 ft ceilings may have an entry closet with a ceiling lowered to 8 ft. A hard cover (usually a piece of plywood) is installed at the 10 ft. level above the entry closet. Hard covers become part of the ceiling air barrier and shall be air-tight.

Inset Stapling — In windy areas installers often staple the flanges of faced batts to the sides of the stud in order to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.

Net Free-Area — The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by the screen or louver. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.

Voids — When batt insulation is pushed too far into a wall stud cavity a void is created between the front of the batt and the drywall. Batts shall be fully lofted and fill the cavity front-to-back. Small voids less than ¾ in. deep on the front or back of a batt shall be allowed as long as the total void area is not over 10% of the batt surface area. This definition shall not preclude the practice of inset stapling as long as the void created by the flange inset meets the specification in the definition of inset stapling.

RH3. Raised Floors and Floors Over Garages

- Batts shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.
- Batts shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.
- Insulation shall be in contact with an air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- If the insulation is faced, the facing shall be placed toward the living space.
- Insulation shall be properly supported to avoid gaps, voids, and compression.

RH4. Wall Insulation

RH4.1. Batt Installation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- The batt shall be friction fitted into the cavity unless another support method is used
- Batt insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.

- Non-standard-width cavities shall be filled with batt insulation snuggly fitted into the space without excessive compression.
- Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

RH4.2 Narrow-Framed Cavities

- Non-standard width cavities shall be filled by batt insulation cut to snuggly fit into the space.
- Narrow spaces (two inches or less) at windows, between studs at the building's corners, and at the intersections of partition walls shall be filled with batt insulation snuggly fitted into the space (without excessive compression), loose fill insulation, or expansive or minimally expansive foam.

RH4.3 Special Situations

RH4.3.1 Installations Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities such as; corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. This may have to be done prior to the installation of the exterior sheathing or the stucco lath.

RH4.3.2 Obstructions

- Insulation shall be cut to fit around wiring and plumbing without compression.
- Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least two-thirds of the insulation between the water pipe and the outside. If the pipe is near the outside, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the inside.

RH4.3.3 Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.
- The insulation shall be installed without gaps or excessive compression.

RH4.3.4 Kneewalls and Skylight Shafts

- All kneewalls and skylight shafts shall be insulated to a minimum of R-19.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls and skylight shafts, external surfaces of steel studs must be covered with batts or rigid foam unless otherwise specified on the CF-1R and documented by a form 3R generated by EZFRAME.
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either fitting to the framing, stapling in place with minimal compression, or using other support such as netting.

RH4.3.5 HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, that require combustion air venting, shall be insulated to the same R-value as the exterior walls.

RH4.3.6 Loose Fill Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate.

- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- Loose fill insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Loose fill wall insulation shall be installed to fit around wiring, plumbing, and other obstructions.
- The installer shall certify on forms CF-6R and IC-1 that the manufacturer's minimum weight-per-square-foot requirement has been met.

RH5. Ceiling and Roof Insulation

RH5.1 Batt Insulation

RH5.1.1 General Requirements

- Batts shall be correctly sized to fit snugly at the sides and ends.
- Batts shall be installed so that they will be in contact with the air barrier.
- Where necessary, batts shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batts are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without excessive compression.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts that are taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight (AT) rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RH5.1.2 Special Situations

RH5.1.2.1 Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing if required by California Building Code section 1505.3.
- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RH5.1.2.2 HVAC Platform

- Appropriate batt insulation shall be placed below any plywood platform or cat-walks for HVAC equipment installation and access
- Batts shall be installed so that they will be in contact with the air barrier.

RH5.1.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener.

RH5.2. Loose-Fill Ceiling Insulation

RH5.2.1 General Requirements

- Baffles shall be placed at eaves or soffit vents to keep insulation from blocking eave ventilation. The required net free-ventilation shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the loose-fill insulation
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is completed or the entire drop area shall be filled with loose-fill insulation level with the rest of the attic.
- Attic rulers appropriate to the material installed shall be evenly distributed throughout the attic to verify depth: one ruler for every 250 square feet and clearly readable from the attic access. The rulers shall be scaled to read inches of insulation and the R-value installed.
- Insulation shall be applied underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.
- Insulation shall cover recessed lighting fixtures.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight (AT) rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.
- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and weight-per-square-foot.
- The installer shall certify on forms CF-6R and IC-1 that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The HERS rater shall verify that the manufacturer's minimum weight-per-square-foot requirement has been met for attics insulated with loose-fill mineral-fiber insulation. One sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record the weight-per-square-foot of the sample on the CF-4R.
- The HERS rater shall verify that the manufacturer’s minimum insulation thickness has been installed. For cellulose insulation this verification shall take into account the time that has elapsed since the insulation was installed. If the insulation has been in place less than seven days, the insulation shall be within 1/2 inch of the manufacturer’s minimum required thickness at the time of installation (or greater). If the insulation has been in place for seven days or longer, the manufacturer’s minimum required settled thickness (or greater) shall be in place.

RH5.2.2 Special Situations

RH5.2.2.1 Kneewalls and Skylight Shafts:

- Kneewalls and skylight shafts shall be insulated to a minimum of R-19. If loose fill insulation is used it shall be properly supported with netting or other support material.

RH5.2.2.2 HVAC Platform

- Pressure-fill the areas under any plywood platform or walks for HVAC equipment installation and access or verify that appropriate batt insulation has been installed.

RH5.2.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener.

RH6. Materials

- Materials shall comply with Uniform Building Code (including, but not limited to, 1997 UBC Section 707) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Sections 2602 and 707 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.

RH7. Equipment

- Scales - The scales used to weigh density samples shall be accurate to within +/- 0.03 pounds. Scales shall be calibrated in accordance with manufacture's instructions.

RH8. R-Value and U-Value Specifications

See CF-1R for minimum R-value requirements; for non-standard assemblies, also see applicable form 3R.

RH9. Certificates

An Insulation Certificate (IC-1) signed by the insulation installer shall be provided that states that the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of loose-fill insulation, the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-Value, and the number of inches required to achieve the desired R-Value. The insulation installer shall also complete a form CF-6R and attach a bag label or a manufacturer's coverage chart for every insulation material used.

RH10. Certificate Availability

The Insulation Certificate (IC-1) and Installation Certificate (CF-6R, with insulation material bag labels or coverage charts attached), signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

CF-6R & CF-4R Insulation Installation Quality Certificate

NOTE: THE FOLLOWING FORM IS PROVIDED FOR INFORMATION. IT WILL LIKELY BE INCLUDED IN THE RESIDENTIAL CONSERVATION MANUAL AND NOT IN THE ACM MANUAL.

Site Address____ Permit ___________

□ Installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-6R only)

□ Insulation certificate, (IC-1) signed by the installer stating: insulation manufacturer's name, material identification, installed R-values, and for loose-fill insulation: minimum weight per square foot and minimum inches

□ Installation Certificate, (CF-6R) signed by the installer certifying that the installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-4R only)

1. FLOOR

□ All floor joist cavity insulation installed to uniformly fit the cavity side-to-side and end-to-end

□ Insulation in contact with the subfloor or rim joists insulated

□ Insulation properly supported to avoid gaps, voids, and compression

2. WALLS

□ Wall stud cavities caulked or foamed to provide an air tight envelope

□ Wall stud cavity insulation uniformly fills the cavity side-to-side, top-to-bottom, and front-to-back

□ No gaps

□ No voids over 3/4" deep or more than 10% of the batt surface area.

□ Hard to access wall stud cavities such as; corner channels, wall intersections, and behind tub/shower enclosures insulated to proper R-Value

□ Small spaces filled

□ Rim-joists insulated

□ Loose fill wall insulation meets or exceeds manufacturer's minimum weight-per-square-foot requirement. (CF-6R only)

3. ROOF/CEILING PREPARATION

□ All draft stops in place to form a continuous ceiling and wall air barrier

□ All drops covered with hard covers

□ All draft stops and hard covers caulked or foamed to provide an air tight envelope

□ All recessed light fixtures IC and air tight (AT) rated and sealed with a gasket or caulk between the housing and the ceiling

□ Floor cavities on multiple-story buildings have air tight draft stops to all adjoining attics

□ Eave vents prepared for blown insulation - maintain net free-ventilation area

□ Kneewalls insulated or prepared for blown insulation

□ Area under equipment platforms and cat-walks insulated or accessible for blown insulation

□ Attic rulers installed

4. ROOF/CEILING BATTS

☐ No gaps

☐ No voids over ¾ in. deep or more than 10% of the batt surface area.

☐ Insulation in contact with the air-barrier

☐ Recessed light fixtures covered

☐ Net free-ventilation area maintained at eave vents

5. ROOF/CEILING LOOSE-FILL

☐ Insulation uniformly covers the entire ceiling (or roof) area from the outside of all exterior walls.

☐ Baffles installed at eaves vents or soffit vents - maintain net free-ventilation area of eave vent

☐ Attic access insulated

☐ Recessed light fixtures covered

☐ Insulation at proper depth – insulation rulers visible and indicating proper depth and R-value

☐ Loose-fill insulation meets or exceeds manufacturer's minimum weight and thickness requirements for the target R-value. Target R-value ____________________ Manufacturer's minimum required weight for the target R-value ____________________ (pounds-per-square-foot). Manufacturer's minimum required thickness at time of installation ________________ Manufacturer's minimum required settled thickness ________________ Note: In order to receive compliance credit the HERS rater shall verify that the manufacturer's minimum weight and thickness has been achieved for the target R-value. (CF-6R only)

☐ Loose-fill mineral fiber insulation meets or exceeds manufacturer's minimum weight and thickness requirement for the target R-value. Target R-value _______________________ Manufacturer's minimum required weight for the target R-value ________________________ (pounds-per-square foot). Sample weight _______________________ (pounds per square foot). (CF-4R only)

☐ Manufacturer's minimum required thickness at time of installation ________________ (inches) Manufacturer's minimum required settled thickness ________________ (inches). Number of days since loose-fill insulation was installed ________________ (days). If the loose-fill insulation has been in place less than seven days the thickness shall be within 1/2 inch of the manufacturer's minimum required thickness at the time of installation (or greater). If the insulation has been in place for seven days or longer the manufacturer's minimum required settled thickness (or greater) shall be in place. Minimum thickness measured _______________ (inches). (CF-4R only)

DECLARATION

I hereby certify that the installation meets all applicable requirements as specified in the Insulation Installation Procedures.

Item #s	Signature, Date	Title, Company Name
Item #s	Signature, Date	Title, Company Name
Item #s	Signature, Date	Title, Company Name

~~APPENDIX H~~

~~Glossary of Terms~~

~~**Approved,** as to a home energy rating provider or home energy rating system, means reviewed and approved by the Commission under Section 1675.~~

~~**Certified**, as to a home energy rater, means having been found by a certified home energy rating provider to have successfully completed the requirements established by that home energy rating provider.~~

~~**Home Energy Rater** means a person certified to perform the site inspection and data collection, diagnostic testing, and data entry and analysis required to produce a home energy rating.~~

~~**Home Energy Rating** means a representation on a 0 to 100 scale of the annual source energy efficiency of a building.~~

~~**Home Energy Rating Provider** means a person or entity that administers an approved home energy rating system.~~

~~**Home Energy Rating System** means a fixed set of procedures, utilizing specifically defined assumptions, measurements and calculations, which produces a home energy rating.~~

~~**Low-Rise Residential Building** means a building, other than a hotel/motel as defined in Title 24, Part 6, Section 101(b), of the California Code of Regulations, that is of occupancy group R-I and is three stories or less, or that is of occupancy group R-3, as those occupancy groups are defined in Title 24, Part 2, Section 1201, of the California Code of Regulations~~

ACM RI-2005

Appendix RI – Procedures for Verifying the Presence of a Thermostatic Expansion Valve or High Energy Efficiency Ratio Equipment

RI-1 Purpose and Scope

The purpose of these procedures is to verify that residential space cooling systems and heat pumps have the required components to achieve the energy efficiency claimed in the compliance documents. The procedures only apply when a TXV is specified for split system equipment or an EER higher than the default is claimed. For dwelling units with multiple systems, the procedures shall be applied to each system separately.

The installer shall certify to the builder, building official and HERS rater that he/she has installed all the correct components.

The reference method algorithms adjust (improve) the efficiency of air conditioners and heat pumps when field verification indicates the specified components are installed. Table RI1 summarizes the algorithms that are affected.

Table RI-1 – SUMMARY OF FIELD VERIFICATION

Diagnostic	Variables and Equation Reference	Description	Standard Design Value	Proposed Design: Default Value	Proposed Design: Procedure
Presence of a TXV	F_{TXV} (Eq. F4-42 and F4-43)	F_{TXV} takes on a value of 0.96 when the system has a verified TXV or has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{TXV} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a TXV, when required by Package D.	No TXV or refrigerant charge testing.	RI2
Presence of a matched High Efficiency Compressor Unit, Evaporator Coil, Refrigerant Metering Device, and (where specified) Air Handling Unit and/or Time Delay Relay.	EER	The EER is the Energy Efficiency Ratio at 95 F outdoors specified according to ARI procedures for the matched combination	Systems are assumed to have the default EER based on SEER, see ACM Equation 4.44.	Default EER	RI 3 and RI4

RI-2 TXV Verification Procedure

The procedure shall consist of visual verification that the TXV is installed on the system.

RI-3 Time Delay Relay Verification Procedure

When a high EER system specification includes a time delay relay, the installation of the time delay relay shall be verified.

The procedure shall be:

1) Turn the thermostat down until the compressor and indoor fan are both running.

2) Turn the thermostat up so the compressor stops running.

3) Verify that the indoor fan continues to run for at least 30 seconds.

RI-4 Matched Equipment Procedure

When installation of specific matched equipment is necessary to achieve a high EER, installation of the specific equipment shall be verified.

The procedure shall consist of visual verification of installation of the following equipment and confirmation that the installed equipment matches the equipment required to achieve the high EER rating:

1) The specified labeled make and model number of the outdoor unit.

2) The specified labeled make and model number of the inside coil.

3) The specified labeled make and model of the furnace or air handler when a specific furnace or air handler is necessary to achieve the high EER rating,

4) The specified metering device when a specific refrigerant metering device (such as a TXV or an EXV) is necessary to achieve the high efficiency rating.

~~APPENDIX I~~

~~*Appendix I: Interior Mass Capacity*~~

~~The *Interior Mass Capacity (IMC)* of a material is calculated by multiplying its *Area* times its *Unit Interior Mass Capacity (UIMC)* using Equation I-1. Tables 3-2a, 3-2b and 3-3 list the UIMCs for a number of thermal mass materials. This method allows for multiple mass types in both raised-floor and slab-on-grade construction.~~

~~The *Interior Mass Capacity* for the *Standard Design* shall be determined as 20 percent of the *Proposed Design's* conditioned slab floor as 3.5 inch thick exposed slab (UIMC=4.6), 80% of the conditioned slab as 3.5 inch thick rug-covered slab (UIMC=1.8), and 5% of the *Proposed Design's* conditioned nonslab floor area as exposed 2 inch thick concrete (UIMC=2.5). If the user does not specify a high mass design, the *Interior Mass Capacity* of the *Proposed Design* shall be the same as for the *Standard Design*. If the user specifies a high mass design with an *Interior Mass Capacity* greater than the high mass threshold, the user is allowed to model the mass specified in the *Proposed Design*. The high mass threshold *Interior Mass* Capacity is determined as 30% of the conditioned floor area as exposed slab (UIMC=4.6), 70% of the conditioned slab floor area as rug-covered slab (UIMC=1.8), and 15% of the conditioned nonslab floor area as 2 inch thick concrete (UIMC=2.5).~~

~~*EQUATION NO. I-1*~~

~~*CALCULATION OF INTERIOR MASS CAPACITY*~~

~~$IMC = [(A_1 \times UIMC_1) + (A_2 \times UIMC_2) \ldots\ldots + (A_n \times UIMC_n)]$~~

~~*Where,*~~

~~A_n = *Area of mass material n, and*~~

~~$UIMC_n$ = *Unit Interior Mass Capacity of mass material n*~~

~~*Based on the UIMCs given above:*~~

~~$IMC_{threshold} = 2.64 \times CSA + 0.375 \times (CFA - CSA)$~~

~~*Where:*~~

~~*CSA = Conditioned Slab floor Area*~~

~~*CFA = total Conditioned Floor Area*~~

~~**Table 3-2a: Interior Mass UIMC Values:**~~

~~**Interior Mass[11] – Surfaces Exposed on One Side[13]**~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Unit Interior Mass Capacity~~
~~Concrete Slab-on-Grade and Raised Concrete Floors~~	~~Exposed[1]~~	~~2.00~~	~~3.6~~
		~~3.50~~	~~4.6~~
		~~6.00~~	~~5.1~~
	~~Covered[2]~~	~~2.00~~	~~1.6~~
		~~3.50~~	~~1.8~~
		~~6.00~~	~~1.9~~
~~Lightweight Concrete[9]~~	~~Exposed~~	~~0.75~~	~~1.0~~
		~~1.00~~	~~1.4~~
		~~1.50~~	~~2.0~~
		~~2.00~~	~~2.5~~
	~~Covered~~	~~0.75~~	~~0.9~~
		~~1.00~~	~~1.0~~
		~~1.50~~	~~1.2~~
		~~2.00~~	~~1.4~~
~~Solid Wood[9]~~	~~Exposed~~	~~1.50~~	~~1.2~~
		~~3.00~~	~~1.6~~
~~Tile[3,9]~~	~~Exposed~~	~~0.50~~	~~0.8~~
		~~1.00~~	~~1.7~~
		~~1.50~~	~~2.4~~
		~~2.00~~	~~3.0~~

~~Masonry[4,9]~~	~~Exposed~~	~~1.00~~	~~2.0~~
		~~2.00~~	~~2.7~~
		~~4.00~~	~~4.2~~
~~Adobe[9]~~	~~Exposed~~	~~4.00~~	~~3.8~~
		~~6.00~~	~~3.9~~
		~~8.00~~	~~3.9~~
~~Framed Wall~~	~~0.50" Gypsum~~	~~na~~	~~0.0~~
	~~0.63" Gypsum~~	~~na~~	~~0.1~~
	~~1.00" Gypsum~~	~~na~~	~~0.5~~
	~~0.88" Stucco~~	~~na~~	~~1.1~~
~~Masonry Infill[7]~~	~~0.50" Gypsum~~	~~3.50~~	~~1.3~~

~~Table 3-2 continued on next page.~~

~~Table 3-2b: Interior Mass UIMC Values:~~

~~Interior Mass[11] - Surfaces Exposed on Two Sides[5, 13]~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Unit Interior Mass Capacity~~
~~Partial Grout Masonry[4]~~	~~Exposed[1]~~	~~4.00~~	~~6.9~~
		~~6.00~~	~~7.4~~
		~~8.00~~	~~7.4~~
~~Solid Grout Masonry[4,6]~~	~~Exposed~~	~~4.00~~	~~8.3~~
		~~6.00~~	~~9.2~~
		~~8.00~~	~~9.6~~
~~Adobe~~	~~Exposed~~	~~4.00~~	~~7.6~~
		~~12.00~~	~~7.8~~
		~~16.00~~	~~7.6~~

~~Solid Wood/~~	~~Exposed~~	~~3.00~~	~~3.3~~
~~Logs~~		~~4.00~~	~~3.3~~
		~~6.00~~	~~3.3~~
		~~8.00~~	~~3.3~~
~~Framed Wall~~	~~0.50" Gypsum~~	~~na~~	~~0.0~~
	~~0.63" Gypsum~~	~~na~~	~~0.2~~
	~~1.00" Gypsum~~	~~na~~	~~0.9~~
	~~0.88" Stucco~~	~~na~~	~~2.1~~
~~Masonry Infill[7]~~	~~0.50" Gypsum~~	~~3.50~~	~~2.6~~

~~Notes follow Table 3-3.~~

~~Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors~~~~[13]~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Wall U-value~~	~~Unit Interior Mass Capacity~~	~~Exterior[8] Mass Factor~~
~~Partial Grout~~	~~Exposed[1]~~	~~4.00~~	~~0.68~~	~~0.9~~	~~1.1~~
~~Masonry~~[4]			~~0.58~~	~~1.0~~	~~1.0~~
		~~6.00~~	~~0.54~~	~~1.3~~	~~1.3~~
			~~0.44~~	~~1.5~~	~~1.1~~
		~~8.00~~	~~0.49~~	~~1.5~~	~~1.3~~
			~~0.38~~	~~1.7~~	~~1.2~~
	~~Furred[10]~~	~~4.00~~	~~0.40~~	~~0.5~~	~~0.9~~
			~~0.30~~	~~0.5~~	~~0.7~~
			~~0.20~~	~~0.5~~	~~0.5~~
			~~0.10~~	~~0.5~~	~~0.3~~
			~~0.08~~	~~0.5~~	~~0.2~~
		~~6.00~~	~~0.40~~	~~0.9~~	~~1.2~~
			~~0.30~~	~~0.6~~	~~1.0~~
			~~0.20~~	~~0.5~~	~~0.7~~
			~~0.10~~	~~0.5~~	~~0.4~~
			~~0.08~~	~~0.5~~	~~0.3~~
		~~8.00~~	~~0.30~~	~~0.8~~	~~1.0~~
			~~0.20~~	~~0.5~~	~~0.7~~
			~~0.10~~	~~0.5~~	~~0.4~~
			~~0.08~~	~~0.5~~	~~0.3~~
~~Solid Grout~~	~~Exposed~~	~~4.00~~	~~0.79~~	~~1.0~~	~~1.4~~
~~Masonry~~[4,6]		~~6.00~~	~~0.68~~	~~1.5~~	~~1.9~~
		~~8.00~~	~~0.62~~	~~1.8~~	~~2.1~~
	~~Furred[10]~~	~~4.00~~	~~0.40~~	~~0.5~~	~~1.0~~
			~~0.30~~	~~0.5~~	~~0.8~~

		~~0.20~~	~~0.5~~	~~0.6~~
		~~0.10~~	~~0.5~~	~~0.3~~
		~~0.08~~	~~0.5~~	~~0.3~~
	~~6.00~~	~~0.40~~	~~0.7~~	~~1.4~~
		~~0.30~~	~~0.5~~	~~1.1~~
		~~0.20~~	~~0.5~~	~~0.7~~
		~~0.10~~	~~0.5~~	~~0.4~~
		~~0.08~~	~~0.5~~	~~0.3~~
	~~8.00~~	~~0.40~~	~~0.8~~	~~1.5~~
		~~0.30~~	~~0.6~~	~~1.2~~
		~~0.20~~	~~0.5~~	~~0.8~~
		~~0.10~~	~~0.5~~	~~0.4~~
		~~0.08~~	~~0.5~~	~~0.3~~

~~Table 3-3 continued on next page~~

~~**Table 3-3: Exterior Wall Mass UIMC Values and Exterior Mass Factors[13]**~~

~~Material~~	~~Surface Condition~~	~~Mass Thickness (inches)~~	~~Wall U-value~~	~~Unit Interior Mass Capacity~~	~~Exterior[9] Mass Factor~~
~~Solid Wood/~~	~~Exposed[1]~~	~~3.00~~	~~0.22~~	~~0.7~~	~~0.5~~
~~Logs~~		~~4.00~~	~~0.17~~	~~0.9~~	~~0.6~~
		~~6.00~~	~~0 .12~~	~~1.1~~	~~0.6~~
		~~8.00~~	~~0.093~~	~~1.2~~	~~0.4~~
		~~10.00~~	~~0.075~~	~~1.3~~	~~0.3~~
		~~12.00~~	~~0.063~~	~~1 .3~~	~~0.3~~
~~Wood Cavity~~	~~Exposed~~	~~3.00[12]~~	~~0.11~~	~~1.1~~	~~0.5~~
~~Wall[12]~~			~~0.065~~	~~1.3~~	~~0.3~~
			~~0.045~~	~~1.4~~	~~0.2~~
~~Adobe~~	~~Exposed~~	~~8.00~~	~~0.35~~	~~2.1~~	~~1.5~~
		~~16.00~~	~~0.21~~	~~2.8~~	~~0.8~~
		~~24.00~~	~~0.15~~	~~3.1~~	~~0.5~~
~~Masonry~~	~~Framed Wall~~	~~4.00~~	~~0.10~~	~~na~~	~~0.3~~
~~Veneer[4]~~			~~0.08~~	~~na~~	~~0.3~~
			~~0.06~~	~~na~~	~~0.2~~
~~Adobe~~	~~Framed Wall~~	~~4.00~~	~~0.10~~	~~na~~	~~0.4~~
~~Veneer~~			~~0.08~~	~~na~~	~~0.3~~
			~~0.06~~	~~na~~	~~0.2~~

~~**Notes For Tables 3-2 and 3-3:**~~

1. ~~"Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.~~
2. ~~"Covered" includes carpet, cabinets, closets or walls.~~
3. ~~The indicated thickness includes both the tile and the mortar bed, when applicable.~~
4. ~~Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.~~

5. ~~The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.~~

6. ~~"Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.~~

7. ~~The indicated thickness for masonry infill is for the masonry material itself.~~

8. ~~Use the Exterior Mass value for calculating Exterior Wall Mass.~~

9. ~~Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.~~

10. ~~"Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.~~

11. ~~When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.~~

12. ~~This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.~~

13. ~~Values based on properties of materials listed in 1993 *ASHRAE Handbook of Fundamentals.*~~

~~APPENDIX J~~

							Climate Zone 1				Climate Zone 2			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.750	0.810	0.779	0.812	0.737	0.674	0.767	0.702
2	Attic	4.2	No	No		Yes	0.750	0.791	0.779	0.800	0.737	0.696	0.767	0.723
3	Attic	4.2	No	Yes		No	0.750	0.875	0.779	0.878	0.737	0.728	0.767	0.759
4	Attic	4.2	No	Yes		Yes	0.750	0.855	0.779	0.864	0.737	0.752	0.767	0.781
5	Attic	4.2	No	Yes	25%	No	0.773	0.877	0.795	0.879	0.762	0.754	0.783	0.776
6	Attic	4.2	No	Yes	25%	Yes	0.773	0.862	0.795	0.869	0.762	0.776	0.783	0.797
7	Attic	4.2	Yes	No		No	0.820	0.866	0.852	0.869	0.811	0.744	0.843	0.775
8	Attic	4.2	Yes	No		Yes	0.820	0.846	0.852	0.855	0.811	0.760	0.843	0.790
9	Attic	4.2	Yes	Yes		No	0.820	0.937	0.852	0.939	0.811	0.804	0.843	0.837
10	Attic	4.2	Yes	Yes		Yes	0.820	0.914	0.852	0.925	0.811	0.822	0.843	0.854
11	Attic	4.2	Yes	Yes	25%	No	0.846	0.938	0.869	0.941	0.838	0.832	0.861	0.856
12	Attic	4.2	Yes	Yes	25%	Yes	0.846	0.922	0.869	0.930	0.838	0.848	0.861	0.871
13	Attic	8.0	No	No		No	0.793	0.813	0.810	0.814	0.783	0.717	0.800	0.734
14	Attic	8.0	No	No		Yes	0.793	0.802	0.810	0.807	0.783	0.735	0.800	0.751
15	Attic	8.0	No	Yes		No	0.793	0.879	0.810	0.880	0.783	0.776	0.800	0.793
16	Attic	8.0	No	Yes		Yes	0.793	0.867	0.810	0.872	0.783	0.795	0.800	0.812
17	Attic	8.0	No	Yes	25%	No	0.807	0.880	0.819	0.881	0.797	0.790	0.810	0.803
18	Attic	8.0	No	Yes	25%	Yes	0.807	0.871	0.819	0.875	0.797	0.809	0.810	0.821
19	Attic	8.0	Yes	No		No	0.868	0.869	0.886	0.871	0.861	0.792	0.880	0.810
20	Attic	8.0	Yes	No		Yes	0.868	0.858	0.886	0.863	0.861	0.804	0.880	0.821
21	Attic	8.0	Yes	Yes		No	0.868	0.940	0.886	0.942	0.861	0.857	0.880	0.876
22	Attic	8.0	Yes	Yes		Yes	0.868	0.927	0.886	0.933	0.861	0.869	0.880	0.888
23	Attic	8.0	Yes	Yes	25%	No	0.883	0.941	0.896	0.942	0.877	0.873	0.891	0.887
24	Attic	8.0	Yes	Yes	25%	Yes	0.883	0.932	0.896	0.936	0.877	0.884	0.891	0.897
25	Crawlspace	4.2	No	No		No	0.755	0.833	0.783	0.828	0.743	0.709	0.772	0.726
26	Crawlspace	4.2	No	No		Yes	0.755	0.833	0.783	0.828	0.743	0.722	0.772	0.741
27	Crawlspace	4.2	No	Yes		No	0.755	0.900	0.783	0.895	0.743	0.767	0.772	0.785
28	Crawlspace	4.2	No	Yes		Yes	0.755	0.900	0.783	0.895	0.743	0.780	0.772	0.801
29	Crawlspace	4.2	No	Yes	25%	No	0.777	0.896	0.798	0.893	0.766	0.783	0.787	0.796
30	Crawlspace	4.2	No	Yes	25%	Yes	0.777	0.896	0.798	0.893	0.766	0.797	0.787	0.812
31	Crawlspace	4.2	Yes	No		No	0.824	0.889	0.855	0.884	0.815	0.781	0.847	0.799
32	Crawlspace	4.2	Yes	No		Yes	0.824	0.889	0.855	0.884	0.815	0.787	0.847	0.807
33	Crawlspace	4.2	Yes	Yes		No	0.824	0.962	0.855	0.956	0.815	0.844	0.847	0.864
34	Crawlspace	4.2	Yes	Yes		Yes	0.824	0.962	0.855	0.956	0.815	0.851	0.847	0.873
~~35~~	~~Crawlspace~~	~~4.2~~	~~Yes~~	~~Yes~~	~~25%~~	~~No~~	~~0.849~~	~~0.958~~	~~0.871~~	~~0.954~~	~~0.841~~	~~0.863~~	~~0.864~~	~~0.877~~
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.849	0.958	0.871	0.954	0.841	0.869	0.864	0.886
37	Crawlspace	8.0	No	No		No	0.797	0.827	0.813	0.824	0.787	0.739	0.804	0.749
38	Crawlspace	8.0	No	No		Yes	0.797	0.827	0.813	0.824	0.787	0.751	0.804	0.762
39	Crawlspace	8.0	No	Yes		No	0.797	0.894	0.813	0.891	0.787	0.798	0.804	0.809
40	Crawlspace	8.0	No	Yes		Yes	0.797	0.894	0.813	0.891	0.787	0.812	0.804	0.824
41	Crawlspace	8.0	No	Yes	25%	No	0.810	0.892	0.822	0.889	0.801	0.808	0.813	0.816
42	Crawlspace	8.0	No	Yes	25%	Yes	0.810	0.892	0.822	0.889	0.801	0.822	0.813	0.831
43	Crawlspace	8.0	Yes	No		No	0.870	0.883	0.888	0.880	0.864	0.814	0.882	0.825
44	Crawlspace	8.0	Yes	No		Yes	0.870	0.883	0.888	0.880	0.864	0.819	0.882	0.832
45	Crawlspace	8.0	Yes	Yes		No	0.870	0.955	0.888	0.952	0.864	0.880	0.882	0.892
46	Crawlspace	8.0	Yes	Yes		Yes	0.870	0.955	0.888	0.952	0.864	0.886	0.882	0.899
47	Crawlspace	8.0	Yes	Yes	25%	No	0.885	0.952	0.898	0.950	0.879	0.891	0.893	0.899
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.885	0.952	0.898	0.950	0.879	0.897	0.893	0.906
49	DuctsInEx12	4.2	No	No		No	0.837	0.816	0.837	0.816	0.829	0.761	0.827	0.760
50	DuctsInEx12	4.2	No	No		Yes	0.837	0.814	0.837	0.815	0.829	0.776	0.827	0.776
51	DuctsInEx12	4.2	No	Yes		No	0.837	0.882	0.837	0.882	0.829	0.823	0.827	0.821
52	DuctsInEx12	4.2	No	Yes		Yes	0.837	0.880	0.837	0.881	0.829	0.839	0.827	0.839
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.916	0.873	0.915	0.873	0.912	0.841	0.910	0.838
56	DuctsInEx12	4.2	Yes	No		Yes	0.916	0.871	0.915	0.872	0.912	0.848	0.910	0.848
57	DuctsInEx12	4.2	Yes	Yes		No	0.916	0.944	0.915	0.944	0.912	0.909	0.910	0.906
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.916	0.942	0.915	0.943	0.912	0.917	0.910	0.917
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.843	0.816	0.843	0.816	0.836	0.768	0.835	0.767
62	DuctsInEx12	8.0	No	No		Yes	0.843	0.815	0.843	0.816	0.836	0.782	0.835	0.782
63	DuctsInEx12	8.0	No	Yes		No	0.843	0.883	0.843	0.883	0.836	0.830	0.835	0.829
64	DuctsInEx12	8.0	No	Yes		Yes	0.843	0.881	0.843	0.882	0.836	0.845	0.835	0.845
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.923	0.873	0.923	0.874	0.920	0.848	0.919	0.847
68	DuctsInEx12	8.0	Yes	No		Yes	0.923	0.872	0.923	0.873	0.920	0.855	0.919	0.854
69	DuctsInEx12	8.0	Yes	Yes		No	0.923	0.944	0.923	0.944	0.920	0.917	0.919	0.916
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.923	0.943	0.923	0.944	0.920	0.924	0.919	0.924
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 3				Climate Zone 4			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.759	0.730	0.788	0.755	0.753	0.738	0.782	0.763
2	Attic	4.2	No	No		Yes	0.759	0.740	0.788	0.766	0.753	0.744	0.782	0.769
3	Attic	4.2	No	Yes		No	0.759	0.789	0.788	0.816	0.753	0.798	0.782	0.824
4	Attic	4.2	No	Yes		Yes	0.759	0.801	0.788	0.828	0.753	0.804	0.782	0.831
5	Attic	4.2	No	Yes	25%	No	0.782	0.809	0.803	0.830	0.776	0.817	0.797	0.837
6	Attic	4.2	No	Yes	25%	Yes	0.782	0.820	0.803	0.841	0.776	0.823	0.797	0.844
7	Attic	4.2	Yes	No		No	0.827	0.786	0.858	0.813	0.822	0.792	0.854	0.818
8	Attic	4.2	Yes	No		Yes	0.827	0.792	0.858	0.819	0.822	0.795	0.854	0.822
9	Attic	4.2	Yes	Yes		No	0.827	0.850	0.858	0.879	0.822	0.856	0.854	0.885
10	Attic	4.2	Yes	Yes		Yes	0.827	0.856	0.858	0.886	0.822	0.860	0.854	0.888
11	Attic	4.2	Yes	Yes	25%	No	0.852	0.871	0.875	0.893	0.848	0.877	0.871	0.898
12	Attic	4.2	Yes	Yes	25%	Yes	0.852	0.877	0.875	0.900	0.848	0.880	0.871	0.902
13	Attic	8.0	No	No		No	0.801	0.763	0.817	0.778	0.795	0.770	0.812	0.784
14	Attic	8.0	No	No		Yes	0.801	0.772	0.817	0.787	0.795	0.775	0.812	0.789
15	Attic	8.0	No	Yes		No	0.801	0.825	0.817	0.841	0.795	0.832	0.812	0.847
16	Attic	8.0	No	Yes		Yes	0.801	0.835	0.817	0.851	0.795	0.838	0.812	0.853
17	Attic	8.0	No	Yes	25%	No	0.814	0.837	0.826	0.848	0.809	0.843	0.821	0.855
18	Attic	8.0	No	Yes	25%	Yes	0.814	0.847	0.826	0.859	0.809	0.849	0.821	0.861
19	Attic	8.0	Yes	No		No	0.873	0.822	0.891	0.837	0.869	0.826	0.888	0.841
20	Attic	8.0	Yes	No		Yes	0.873	0.827	0.891	0.843	0.869	0.829	0.888	0.844
21	Attic	8.0	Yes	Yes		No	0.873	0.888	0.891	0.905	0.869	0.893	0.888	0.909
22	Attic	8.0	Yes	Yes		Yes	0.873	0.894	0.891	0.911	0.869	0.896	0.888	0.913
23	Attic	8.0	Yes	Yes	25%	No	0.887	0.901	0.900	0.914	0.884	0.905	0.898	0.917
24	Attic	8.0	Yes	Yes	25%	Yes	0.887	0.906	0.900	0.919	0.884	0.908	0.898	0.921
25	Crawlspace	4.2	No	No		No	0.764	0.762	0.792	0.777	0.758	0.770	0.786	0.784
26	Crawlspace	4.2	No	No		Yes	0.764	0.770	0.792	0.786	0.758	0.774	0.786	0.789
27	Crawlspace	4.2	No	Yes		No	0.764	0.824	0.792	0.840	0.758	0.832	0.786	0.848
28	Crawlspace	4.2	No	Yes		Yes	0.764	0.833	0.792	0.850	0.758	0.837	0.786	0.853
29	Crawlspace	4.2	No	Yes	25%	No	0.786	0.836	0.806	0.848	0.780	0.844	0.801	0.855
30	Crawlspace	4.2	No	Yes	25%	Yes	0.786	0.845	0.806	0.858	0.780	0.849	0.801	0.861
31	Crawlspace	4.2	Yes	No		No	0.830	0.819	0.861	0.835	0.826	0.824	0.857	0.840
32	Crawlspace	4.2	Yes	No		Yes	0.830	0.823	0.861	0.840	0.826	0.827	0.857	0.843
33	Crawlspace	4.2	Yes	Yes		No	0.830	0.885	0.861	0.903	0.826	0.891	0.857	0.908
34	Crawlspace	4.2	Yes	Yes		Yes	0.830	0.890	0.861	0.908	0.826	0.894	0.857	0.911
35	Crawlspace	4.2	Yes	Yes	25%	No	0.855	0.899	0.877	0.911	0.851	0.904	0.873	0.916
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.855	0.903	0.877	0.917	0.851	0.906	0.873	0.920
37	Crawlspace	8.0	No	No		No	0.804	0.782	0.820	0.791	0.799	0.789	0.816	0.797
38	Crawlspace	8.0	No	No		Yes	0.804	0.790	0.820	0.800	0.799	0.793	0.816	0.802
39	Crawlspace	8.0	No	Yes		No	0.804	0.846	0.820	0.855	0.799	0.853	0.816	0.862
40	Crawlspace	8.0	No	Yes		Yes	0.804	0.855	0.820	0.865	0.799	0.857	0.816	0.867
41	Crawlspace	8.0	No	Yes	25%	No	0.817	0.853	0.829	0.860	0.812	0.859	0.824	0.866
42	Crawlspace	8.0	No	Yes	25%	Yes	0.817	0.862	0.829	0.869	0.812	0.864	0.824	0.871
43	Crawlspace	8.0	Yes	No		No	0.875	0.841	0.893	0.850	0.872	0.845	0.890	0.854
44	Crawlspace	8.0	Yes	No		Yes	0.875	0.845	0.893	0.855	0.872	0.847	0.890	0.856
45	Crawlspace	8.0	Yes	Yes		No	0.875	0.909	0.893	0.919	0.872	0.914	0.890	0.923
46	Crawlspace	8.0	Yes	Yes		Yes	0.875	0.913	0.893	0.924	0.872	0.916	0.890	0.926
47	Crawlspace	8.0	Yes	Yes	25%	No	0.889	0.917	0.902	0.924	0.886	0.921	0.899	0.928
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.889	0.921	0.902	0.929	0.886	0.923	0.899	0.931
49	DuctsInEx12	4.2	No	No		No	0.843	0.799	0.843	0.800	0.839	0.804	0.839	0.806
50	DuctsInEx12	4.2	No	No		Yes	0.843	0.808	0.843	0.811	0.839	0.809	0.839	0.812
51	DuctsInEx12	4.2	No	Yes		No	0.843	0.863	0.843	0.865	0.839	0.869	0.839	0.871
52	DuctsInEx12	4.2	No	Yes		Yes	0.843	0.873	0.843	0.876	0.839	0.875	0.839	0.878
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.920	0.860	0.919	0.862	0.917	0.863	0.917	0.865
56	DuctsInEx12	4.2	Yes	No		Yes	0.920	0.865	0.919	0.868	0.917	0.866	0.917	0.869
57	DuctsInEx12	4.2	Yes	Yes		No	0.920	0.930	0.919	0.932	0.917	0.933	0.917	0.935
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.920	0.935	0.919	0.938	0.917	0.936	0.917	0.939
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.849	0.803	0.849	0.804	0.845	0.808	0.845	0.809
62	DuctsInEx12	8.0	No	No		Yes	0.849	0.811	0.849	0.813	0.845	0.812	0.845	0.814
63	DuctsInEx12	8.0	No	Yes		No	0.849	0.868	0.849	0.869	0.845	0.873	0.845	0.874
64	DuctsInEx12	8.0	No	Yes		Yes	0.849	0.877	0.849	0.879	0.845	0.878	0.845	0.880
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.926	0.865	0.926	0.866	0.924	0.867	0.924	0.868
68	DuctsInEx12	8.0	Yes	No		Yes	0.926	0.869	0.926	0.870	0.924	0.869	0.924	0.871
69	DuctsInEx12	8.0	Yes	Yes		No	0.926	0.935	0.926	0.936	0.924	0.937	0.924	0.939
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.926	0.939	0.926	0.941	0.924	0.940	0.924	0.941
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 5				Climate Zone 6			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.740	0.760	0.770	0.779	0.766	0.722	0.794	0.747
2	Attic	4.2	No	No		Yes	0.740	0.756	0.770	0.777	0.766	0.734	0.794	0.759
3	Attic	4.2	No	Yes		No	0.740	0.822	0.770	0.843	0.766	0.781	0.794	0.808
4	Attic	4.2	No	Yes		Yes	0.740	0.817	0.770	0.840	0.766	0.793	0.794	0.821
5	Attic	4.2	No	Yes	25%	No	0.765	0.837	0.786	0.853	0.788	0.801	0.809	0.822
6	Attic	4.2	No	Yes	25%	Yes	0.765	0.833	0.786	0.850	0.788	0.814	0.809	0.835
7	Attic	4.2	Yes	No		No	0.813	0.813	0.845	0.834	0.832	0.780	0.863	0.807
8	Attic	4.2	Yes	No		Yes	0.813	0.809	0.845	0.831	0.832	0.787	0.863	0.815
9	Attic	4.2	Yes	Yes		No	0.813	0.879	0.845	0.901	0.832	0.843	0.863	0.873
10	Attic	4.2	Yes	Yes		Yes	0.813	0.874	0.845	0.898	0.832	0.851	0.863	0.881
11	Attic	4.2	Yes	Yes	25%	No	0.840	0.895	0.863	0.912	0.856	0.866	0.879	0.888
12	Attic	4.2	Yes	Yes	25%	Yes	0.840	0.891	0.863	0.909	0.856	0.873	0.879	0.896
13	Attic	8.0	No	No		No	0.785	0.784	0.803	0.795	0.806	0.757	0.822	0.771
14	Attic	8.0	No	No		Yes	0.785	0.782	0.803	0.794	0.806	0.767	0.822	0.782
15	Attic	8.0	No	Yes		No	0.785	0.848	0.803	0.860	0.806	0.818	0.822	0.834
16	Attic	8.0	No	Yes		Yes	0.785	0.845	0.803	0.858	0.806	0.829	0.822	0.845
17	Attic	8.0	No	Yes	25%	No	0.799	0.856	0.812	0.866	0.819	0.830	0.831	0.842
18	Attic	8.0	No	Yes	25%	Yes	0.799	0.854	0.812	0.864	0.819	0.841	0.831	0.853
19	Attic	8.0	Yes	No		No	0.863	0.839	0.882	0.851	0.876	0.818	0.894	0.834
20	Attic	8.0	Yes	No		Yes	0.863	0.836	0.882	0.849	0.876	0.823	0.894	0.839
21	Attic	8.0	Yes	Yes		No	0.863	0.907	0.882	0.920	0.876	0.884	0.894	0.901
22	Attic	8.0	Yes	Yes		Yes	0.863	0.904	0.882	0.918	0.876	0.890	0.894	0.908
23	Attic	8.0	Yes	Yes	25%	No	0.878	0.916	0.892	0.926	0.890	0.897	0.903	0.910
24	Attic	8.0	Yes	Yes	25%	Yes	0.878	0.914	0.892	0.925	0.890	0.903	0.903	0.916
25	Crawlspace	4.2	No	No		No	0.746	0.790	0.774	0.800	0.770	0.755	0.797	0.770
26	Crawlspace	4.2	No	No		Yes	0.746	0.790	0.774	0.800	0.770	0.763	0.797	0.780
27	Crawlspace	4.2	No	Yes		No	0.746	0.854	0.774	0.864	0.770	0.816	0.797	0.832
28	Crawlspace	4.2	No	Yes		Yes	0.746	0.854	0.774	0.864	0.770	0.825	0.797	0.843
29	Crawlspace	4.2	No	Yes	25%	No	0.769	0.861	0.790	0.869	0.791	0.828	0.812	0.841
30	Crawlspace	4.2	No	Yes	25%	Yes	0.769	0.861	0.790	0.869	0.791	0.838	0.812	0.851
31	Crawlspace	4.2	Yes	No		No	0.817	0.843	0.849	0.854	0.835	0.813	0.865	0.830
32	Crawlspace	4.2	Yes	No		Yes	0.817	0.843	0.849	0.854	0.835	0.818	0.865	0.835
33	Crawlspace	4.2	Yes	Yes		No	0.817	0.912	0.849	0.923	0.835	0.879	0.865	0.897
34	Crawlspace	4.2	Yes	Yes		Yes	0.817	0.912	0.849	0.923	0.835	0.884	0.865	0.903
35	Crawlspace	4.2	Yes	Yes	25%	No	0.843	0.920	0.866	0.929	0.858	0.893	0.881	0.906
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.843	0.920	0.866	0.929	0.858	0.898	0.881	0.912
37	Crawlspace	8.0	No	No		No	0.789	0.802	0.806	0.808	0.809	0.776	0.825	0.785
38	Crawlspace	8.0	No	No		Yes	0.789	0.802	0.806	0.808	0.809	0.785	0.825	0.794
39	Crawlspace	8.0	No	Yes		No	0.789	0.867	0.806	0.873	0.809	0.839	0.825	0.849
40	Crawlspace	8.0	No	Yes		Yes	0.789	0.867	0.806	0.873	0.809	0.848	0.825	0.859
41	Crawlspace	8.0	No	Yes	25%	No	0.803	0.872	0.815	0.876	0.822	0.847	0.834	0.853
42	Crawlspace	8.0	No	Yes	25%	Yes	0.803	0.872	0.815	0.876	0.822	0.856	0.834	0.864
43	Crawlspace	8.0	Yes	No		No	0.866	0.857	0.884	0.863	0.878	0.837	0.895	0.847
44	Crawlspace	8.0	Yes	No		Yes	0.866	0.857	0.884	0.863	0.878	0.841	0.895	0.851
45	Crawlspace	8.0	Yes	Yes		No	0.866	0.926	0.884	0.933	0.878	0.905	0.895	0.915
46	Crawlspace	8.0	Yes	Yes		Yes	0.866	0.926	0.884	0.933	0.878	0.909	0.895	0.920
47	Crawlspace	8.0	Yes	Yes	25%	No	0.881	0.931	0.894	0.936	0.892	0.913	0.905	0.921
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.881	0.931	0.894	0.936	0.892	0.917	0.905	0.926
49	DuctsInEx12	4.2	No	No		No	0.831	0.811	0.830	0.813	0.848	0.793	0.848	0.794
50	DuctsInEx12	4.2	No	No		Yes	0.831	0.810	0.830	0.813	0.848	0.803	0.848	0.805
51	DuctsInEx12	4.2	No	Yes		No	0.831	0.877	0.830	0.879	0.848	0.858	0.848	0.859
52	DuctsInEx12	4.2	No	Yes		Yes	0.831	0.876	0.830	0.879	0.848	0.868	0.848	0.871
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.913	0.868	0.911	0.870	0.922	0.857	0.922	0.859
56	DuctsInEx12	4.2	Yes	No		Yes	0.913	0.867	0.911	0.869	0.922	0.862	0.922	0.865
57	DuctsInEx12	4.2	Yes	Yes		No	0.913	0.938	0.911	0.940	0.922	0.927	0.922	0.928
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.913	0.937	0.911	0.940	0.922	0.932	0.922	0.935
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.838	0.813	0.837	0.815	0.853	0.798	0.853	0.798
62	DuctsInEx12	8.0	No	No		Yes	0.838	0.813	0.837	0.814	0.853	0.807	0.853	0.808
63	DuctsInEx12	8.0	No	Yes		No	0.838	0.879	0.837	0.881	0.853	0.862	0.853	0.863
64	DuctsInEx12	8.0	No	Yes		Yes	0.838	0.879	0.837	0.880	0.853	0.872	0.853	0.874
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.920	0.870	0.920	0.872	0.928	0.862	0.928	0.863
68	DuctsInEx12	8.0	Yes	No		Yes	0.920	0.870	0.920	0.871	0.928	0.867	0.928	0.868
69	DuctsInEx12	8.0	Yes	Yes		No	0.920	0.941	0.920	0.942	0.928	0.932	0.928	0.933
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.920	0.941	0.920	0.942	0.928	0.937	0.928	0.938
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 7				Climate Zone 8			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.781	0.760	0.809	0.779	0.769	0.752	0.797	0.770
2	Attic	4.2	No	No		Yes	0.781	0.756	0.809	0.777	0.769	0.761	0.797	0.780
3	Attic	4.2	No	Yes		No	0.781	0.822	0.809	0.843	0.769	0.813	0.797	0.832
4	Attic	4.2	No	Yes		Yes	0.781	0.817	0.809	0.840	0.769	0.823	0.797	0.843
5	Attic	4.2	No	Yes	25%	No	0.802	0.837	0.823	0.853	0.791	0.827	0.811	0.842
6	Attic	4.2	No	Yes	25%	Yes	0.802	0.833	0.823	0.850	0.791	0.837	0.811	0.853
7	Attic	4.2	Yes	No		No	0.844	0.813	0.873	0.834	0.834	0.809	0.865	0.829
8	Attic	4.2	Yes	No		Yes	0.844	0.809	0.873	0.831	0.834	0.815	0.865	0.835
9	Attic	4.2	Yes	Yes		No	0.844	0.879	0.873	0.901	0.834	0.875	0.865	0.896
10	Attic	4.2	Yes	Yes		Yes	0.844	0.874	0.873	0.898	0.834	0.881	0.865	0.902
11	Attic	4.2	Yes	Yes	25%	No	0.866	0.895	0.888	0.912	0.858	0.891	0.881	0.906
12	Attic	4.2	Yes	Yes	25%	Yes	0.866	0.891	0.888	0.909	0.858	0.896	0.881	0.913
13	Attic	8.0	No	No		No	0.819	0.784	0.835	0.795	0.808	0.776	0.825	0.786
14	Attic	8.0	No	No		Yes	0.819	0.782	0.835	0.794	0.808	0.785	0.825	0.795
15	Attic	8.0	No	Yes		No	0.819	0.848	0.835	0.860	0.808	0.839	0.825	0.850
16	Attic	8.0	No	Yes		Yes	0.819	0.845	0.835	0.858	0.808	0.848	0.825	0.860
17	Attic	8.0	No	Yes	25%	No	0.831	0.856	0.843	0.866	0.821	0.847	0.833	0.855
18	Attic	8.0	No	Yes	25%	Yes	0.831	0.854	0.843	0.864	0.821	0.857	0.833	0.865
19	Attic	8.0	Yes	No		No	0.884	0.839	0.901	0.851	0.878	0.835	0.895	0.847
20	Attic	8.0	Yes	No		Yes	0.884	0.836	0.901	0.849	0.878	0.840	0.895	0.851
21	Attic	8.0	Yes	Yes		No	0.884	0.907	0.901	0.920	0.878	0.903	0.895	0.915
22	Attic	8.0	Yes	Yes		Yes	0.884	0.904	0.901	0.918	0.878	0.908	0.895	0.920
23	Attic	8.0	Yes	Yes	25%	No	0.897	0.916	0.910	0.926	0.892	0.912	0.905	0.921
24	Attic	8.0	Yes	Yes	25%	Yes	0.897	0.914	0.910	0.925	0.892	0.917	0.905	0.926
25	Crawlspace	4.2	No	No		No	0.784	0.790	0.811	0.800	0.773	0.775	0.800	0.786
26	Crawlspace	4.2	No	No		Yes	0.784	0.790	0.811	0.800	0.773	0.783	0.800	0.795
27	Crawlspace	4.2	No	Yes		No	0.784	0.854	0.811	0.864	0.773	0.838	0.800	0.850
28	Crawlspace	4.2	No	Yes		Yes	0.784	0.854	0.811	0.864	0.773	0.847	0.800	0.860
29	Crawlspace	4.2	No	Yes	25%	No	0.805	0.861	0.825	0.869	0.794	0.847	0.814	0.856
30	Crawlspace	4.2	No	Yes	25%	Yes	0.805	0.861	0.825	0.869	0.794	0.856	0.814	0.866
31	Crawlspace	4.2	Yes	No		No	0.845	0.843	0.875	0.854	0.837	0.833	0.867	0.845
32	Crawlspace	4.2	Yes	No		Yes	0.845	0.843	0.875	0.854	0.837	0.837	0.867	0.850
33	Crawlspace	4.2	Yes	Yes		No	0.845	0.912	0.875	0.923	0.837	0.901	0.867	0.913
34	Crawlspace	4.2	Yes	Yes		Yes	0.845	0.912	0.875	0.923	0.837	0.905	0.867	0.919
35	Crawlspace	4.2	Yes	Yes	25%	No	0.868	0.920	0.890	0.929	0.860	0.911	0.882	0.920
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.868	0.920	0.890	0.929	0.860	0.915	0.882	0.925
37	Crawlspace	8.0	No	No		No	0.821	0.802	0.837	0.808	0.811	0.790	0.828	0.796
38	Crawlspace	8.0	No	No		Yes	0.821	0.802	0.837	0.808	0.811	0.798	0.828	0.805
39	Crawlspace	8.0	No	Yes		No	0.821	0.867	0.837	0.873	0.811	0.854	0.828	0.861
40	Crawlspace	8.0	No	Yes		Yes	0.821	0.867	0.837	0.873	0.811	0.863	0.828	0.870
41	Crawlspace	8.0	No	Yes	25%	No	0.833	0.872	0.845	0.876	0.824	0.859	0.836	0.864
42	Crawlspace	8.0	No	Yes	25%	Yes	0.833	0.872	0.845	0.876	0.824	0.868	0.836	0.874
43	Crawlspace	8.0	Yes	No		No	0.885	0.857	0.903	0.863	0.879	0.849	0.897	0.856
44	Crawlspace	8.0	Yes	No		Yes	0.885	0.857	0.903	0.863	0.879	0.853	0.897	0.860
45	Crawlspace	8.0	Yes	Yes		No	0.885	0.926	0.903	0.933	0.879	0.918	0.897	0.926
46	Crawlspace	8.0	Yes	Yes		Yes	0.885	0.926	0.903	0.933	0.879	0.922	0.897	0.930
47	Crawlspace	8.0	Yes	Yes	25%	No	0.899	0.931	0.911	0.936	0.893	0.924	0.906	0.929
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.899	0.931	0.911	0.936	0.893	0.928	0.906	0.934
49	DuctsInEx12	4.2	No	No		No	0.858	0.811	0.859	0.813	0.850	0.801	0.850	0.802
50	DuctsInEx12	4.2	No	No		Yes	0.858	0.810	0.859	0.813	0.850	0.810	0.850	0.812
51	DuctsInEx12	4.2	No	Yes		No	0.858	0.877	0.859	0.879	0.850	0.866	0.850	0.868
52	DuctsInEx12	4.2	No	Yes		Yes	0.858	0.876	0.859	0.879	0.850	0.876	0.850	0.878
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.927	0.868	0.929	0.870	0.923	0.863	0.923	0.864
56	DuctsInEx12	4.2	Yes	No		Yes	0.927	0.867	0.929	0.869	0.923	0.867	0.923	0.869
57	DuctsInEx12	4.2	Yes	Yes		No	0.927	0.938	0.929	0.940	0.923	0.933	0.923	0.934
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.927	0.937	0.929	0.940	0.923	0.938	0.923	0.940
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.863	0.813	0.864	0.815	0.855	0.804	0.855	0.805
62	DuctsInEx12	8.0	No	No		Yes	0.863	0.813	0.864	0.814	0.855	0.813	0.855	0.814
63	DuctsInEx12	8.0	No	Yes		No	0.863	0.879	0.864	0.881	0.855	0.869	0.855	0.870
64	DuctsInEx12	8.0	No	Yes		Yes	0.863	0.879	0.864	0.880	0.855	0.879	0.855	0.880
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.932	0.870	0.933	0.872	0.929	0.866	0.929	0.867
68	DuctsInEx12	8.0	Yes	No		Yes	0.932	0.870	0.933	0.871	0.929	0.870	0.929	0.871
69	DuctsInEx12	8.0	Yes	Yes		No	0.932	0.941	0.933	0.942	0.929	0.937	0.929	0.937
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.932	0.941	0.933	0.942	0.929	0.941	0.929	0.942
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Case	Duct Location	Duct R-value	Duct Sealing	Duct Design	Area Reduction	Radiant Barrier	Climate Zone 9 One Story Heating	Climate Zone 9 One Story Cooling	Climate Zone 9 Two Story Heating	Climate Zone 9 Two Story Cooling	Climate Zone 10 One Story Heating	Climate Zone 10 One Story Cooling	Climate Zone 10 Two Story Heating	Climate Zone 10 Two Story Cooling
1	Attic	4.2	No	No		No	0.753	0.702	0.782	0.723	0.753	0.674	0.782	0.696
2	Attic	4.2	No	No		Yes	0.753	0.722	0.782	0.741	0.753	0.699	0.782	0.719
3	Attic	4.2	No	Yes		No	0.753	0.759	0.782	0.781	0.753	0.728	0.782	0.752
4	Attic	4.2	No	Yes		Yes	0.753	0.780	0.782	0.801	0.753	0.756	0.782	0.778
5	Attic	4.2	No	Yes	25%	No	0.776	0.778	0.797	0.794	0.776	0.749	0.797	0.766
6	Attic	4.2	No	Yes	25%	Yes	0.776	0.797	0.797	0.813	0.776	0.774	0.797	0.790
7	Attic	4.2	Yes	No		No	0.822	0.775	0.854	0.798	0.822	0.756	0.854	0.780
8	Attic	4.2	Yes	No		Yes	0.822	0.789	0.854	0.810	0.822	0.774	0.854	0.796
9	Attic	4.2	Yes	Yes		No	0.822	0.838	0.854	0.863	0.822	0.817	0.854	0.843
10	Attic	4.2	Yes	Yes		Yes	0.822	0.852	0.854	0.876	0.822	0.836	0.854	0.861
11	Attic	4.2	Yes	Yes	25%	No	0.848	0.859	0.871	0.876	0.848	0.841	0.871	0.859
12	Attic	4.2	Yes	Yes	25%	Yes	0.848	0.871	0.871	0.888	0.848	0.857	0.871	0.874
13	Attic	8.0	No	No		No	0.795	0.734	0.812	0.746	0.795	0.710	0.812	0.723
14	Attic	8.0	No	No		Yes	0.795	0.751	0.812	0.762	0.795	0.731	0.812	0.743
15	Attic	8.0	No	Yes		No	0.795	0.794	0.812	0.806	0.795	0.768	0.812	0.782
16	Attic	8.0	No	Yes		Yes	0.795	0.811	0.812	0.824	0.795	0.790	0.812	0.803
17	Attic	8.0	No	Yes	25%	No	0.809	0.804	0.821	0.814	0.809	0.780	0.821	0.790
18	Attic	8.0	No	Yes	25%	Yes	0.809	0.821	0.821	0.830	0.809	0.801	0.821	0.810
19	Attic	8.0	Yes	No		No	0.869	0.811	0.888	0.824	0.869	0.797	0.888	0.811
20	Attic	8.0	Yes	No		Yes	0.869	0.820	0.888	0.833	0.869	0.809	0.888	0.822
21	Attic	8.0	Yes	Yes		No	0.869	0.876	0.888	0.891	0.869	0.861	0.888	0.876
22	Attic	8.0	Yes	Yes		Yes	0.869	0.887	0.888	0.900	0.869	0.875	0.888	0.889
23	Attic	8.0	Yes	Yes	25%	No	0.884	0.888	0.898	0.898	0.884	0.875	0.898	0.885
24	Attic	8.0	Yes	Yes	25%	Yes	0.884	0.898	0.898	0.908	0.884	0.887	0.898	0.897
25	Crawlspace	4.2	No	No		No	0.758	0.728	0.786	0.741	0.758	0.701	0.786	0.715
26	Crawlspace	4.2	No	No		Yes	0.758	0.741	0.786	0.755	0.758	0.717	0.786	0.732
27	Crawlspace	4.2	No	Yes		No	0.758	0.787	0.786	0.801	0.758	0.758	0.786	0.773
28	Crawlspace	4.2	No	Yes		Yes	0.758	0.801	0.786	0.816	0.758	0.775	0.786	0.791
29	Crawlspace	4.2	No	Yes	25%	No	0.780	0.800	0.801	0.809	0.780	0.772	0.801	0.782
30	Crawlspace	4.2	No	Yes	25%	Yes	0.780	0.814	0.801	0.824	0.780	0.789	0.801	0.801
31	Crawlspace	4.2	Yes	No		No	0.826	0.802	0.857	0.816	0.826	0.784	0.857	0.799
32	Crawlspace	4.2	Yes	No		Yes	0.826	0.808	0.857	0.823	0.826	0.791	0.857	0.808
33	Crawlspace	4.2	Yes	Yes		No	0.826	0.867	0.857	0.882	0.826	0.848	0.857	0.864
34	Crawlspace	4.2	Yes	Yes		Yes	0.826	0.873	0.857	0.890	0.826	0.855	0.857	0.873
35	Crawlspace	4.2	Yes	Yes	25%	No	0.851	0.881	0.873	0.891	0.851	0.864	0.873	0.875
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.851	0.887	0.873	0.899	0.851	0.872	0.873	0.884
37	Crawlspace	8.0	No	No		No	0.799	0.750	0.816	0.757	0.799	0.727	0.816	0.735
38	Crawlspace	8.0	No	No		Yes	0.799	0.762	0.816	0.770	0.799	0.742	0.816	0.751
39	Crawlspace	8.0	No	Yes		No	0.799	0.811	0.816	0.818	0.799	0.786	0.816	0.794
40	Crawlspace	8.0	No	Yes		Yes	0.799	0.824	0.816	0.833	0.799	0.802	0.816	0.812
41	Crawlspace	8.0	No	Yes	25%	No	0.812	0.818	0.824	0.823	0.812	0.794	0.824	0.800
42	Crawlspace	8.0	No	Yes	25%	Yes	0.812	0.831	0.824	0.838	0.812	0.811	0.824	0.817
43	Crawlspace	8.0	Yes	No		No	0.872	0.826	0.890	0.834	0.872	0.813	0.890	0.822
44	Crawlspace	8.0	Yes	No		Yes	0.872	0.832	0.890	0.841	0.872	0.820	0.890	0.829
45	Crawlspace	8.0	Yes	Yes		No	0.872	0.893	0.890	0.902	0.872	0.879	0.890	0.888
46	Crawlspace	8.0	Yes	Yes		Yes	0.872	0.899	0.890	0.909	0.872	0.886	0.890	0.897
47	Crawlspace	8.0	Yes	Yes	25%	No	0.886	0.901	0.899	0.907	0.886	0.888	0.899	0.895
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.886	0.907	0.899	0.914	0.886	0.896	0.899	0.903
49	DuctsInEx12	4.2	No	No		No	0.839	0.766	0.839	0.764	0.839	0.745	0.839	0.743
50	DuctsInEx12	4.2	No	No		Yes	0.839	0.780	0.839	0.780	0.839	0.763	0.839	0.761
51	DuctsInEx12	4.2	No	Yes		No	0.839	0.828	0.839	0.826	0.839	0.806	0.839	0.803
52	DuctsInEx12	4.2	No	Yes		Yes	0.839	0.843	0.839	0.843	0.839	0.825	0.839	0.823
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.917	0.846	0.917	0.844	0.917	0.836	0.917	0.832
56	DuctsInEx12	4.2	Yes	No		Yes	0.917	0.853	0.917	0.852	0.917	0.844	0.917	0.842
57	DuctsInEx12	4.2	Yes	Yes		No	0.917	0.914	0.917	0.912	0.917	0.903	0.917	0.900
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.917	0.922	0.917	0.921	0.917	0.913	0.917	0.911
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.845	0.771	0.845	0.770	0.845	0.751	0.845	0.750
62	DuctsInEx12	8.0	No	No		Yes	0.845	0.784	0.845	0.784	0.845	0.768	0.845	0.767
63	DuctsInEx12	8.0	No	Yes		No	0.845	0.833	0.845	0.832	0.845	0.812	0.845	0.811
64	DuctsInEx12	8.0	No	Yes		Yes	0.845	0.848	0.845	0.847	0.845	0.830	0.845	0.829
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.924	0.851	0.924	0.850	0.924	0.842	0.924	0.841
68	DuctsInEx12	8.0	Yes	No		Yes	0.924	0.857	0.924	0.857	0.924	0.850	0.924	0.849
69	DuctsInEx12	8.0	Yes	Yes		No	0.924	0.920	0.924	0.919	0.924	0.911	0.924	0.909
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.924	0.927	0.924	0.926	0.924	0.919	0.924	0.918
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 11				Climate Zone 12			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.737	0.645	0.767	0.669	0.743	0.674	0.773	0.696
2	Attic	4.2	No	No		Yes	0.737	0.677	0.767	0.698	0.743	0.699	0.773	0.719
3	Attic	4.2	No	Yes		No	0.737	0.698	0.767	0.723	0.743	0.728	0.773	0.752
4	Attic	4.2	No	Yes		Yes	0.737	0.731	0.767	0.754	0.743	0.756	0.773	0.778
5	Attic	4.2	No	Yes	25%	No	0.762	0.721	0.783	0.739	0.767	0.749	0.789	0.766
6	Attic	4.2	No	Yes	25%	Yes	0.762	0.752	0.783	0.768	0.767	0.774	0.789	0.790
7	Attic	4.2	Yes	No		No	0.811	0.737	0.843	0.762	0.815	0.756	0.848	0.780
8	Attic	4.2	Yes	No		Yes	0.811	0.759	0.843	0.782	0.815	0.774	0.848	0.796
9	Attic	4.2	Yes	Yes		No	0.811	0.796	0.843	0.824	0.815	0.817	0.848	0.843
10	Attic	4.2	Yes	Yes		Yes	0.811	0.820	0.843	0.846	0.815	0.836	0.848	0.861
11	Attic	4.2	Yes	Yes	25%	No	0.838	0.822	0.861	0.841	0.842	0.841	0.865	0.859
12	Attic	4.2	Yes	Yes	25%	Yes	0.838	0.843	0.861	0.860	0.842	0.857	0.865	0.874
13	Attic	8.0	No	No		No	0.783	0.686	0.800	0.700	0.788	0.710	0.805	0.723
14	Attic	8.0	No	No		Yes	0.783	0.712	0.800	0.724	0.788	0.731	0.805	0.743
15	Attic	8.0	No	Yes		No	0.783	0.742	0.800	0.757	0.788	0.768	0.805	0.782
16	Attic	8.0	No	Yes		Yes	0.783	0.770	0.800	0.783	0.788	0.790	0.805	0.803
17	Attic	8.0	No	Yes	25%	No	0.797	0.756	0.810	0.766	0.802	0.780	0.814	0.790
18	Attic	8.0	No	Yes	25%	Yes	0.797	0.781	0.810	0.790	0.802	0.801	0.814	0.810
19	Attic	8.0	Yes	No		No	0.861	0.783	0.880	0.798	0.864	0.797	0.883	0.811
20	Attic	8.0	Yes	No		Yes	0.861	0.798	0.880	0.812	0.864	0.809	0.883	0.822
21	Attic	8.0	Yes	Yes		No	0.861	0.846	0.880	0.862	0.864	0.861	0.883	0.876
22	Attic	8.0	Yes	Yes		Yes	0.861	0.863	0.880	0.878	0.864	0.875	0.883	0.889
23	Attic	8.0	Yes	Yes	25%	No	0.877	0.861	0.891	0.872	0.880	0.875	0.893	0.885
24	Attic	8.0	Yes	Yes	25%	Yes	0.877	0.876	0.891	0.886	0.880	0.887	0.893	0.897
25	Crawlspace	4.2	No	No		No	0.743	0.674	0.772	0.689	0.749	0.701	0.777	0.715
26	Crawlspace	4.2	No	No		Yes	0.743	0.692	0.772	0.709	0.749	0.717	0.777	0.732
27	Crawlspace	4.2	No	Yes		No	0.743	0.729	0.772	0.745	0.749	0.758	0.777	0.773
28	Crawlspace	4.2	No	Yes		Yes	0.743	0.749	0.772	0.766	0.749	0.775	0.777	0.791
29	Crawlspace	4.2	No	Yes	25%	No	0.766	0.745	0.787	0.755	0.772	0.772	0.793	0.782
30	Crawlspace	4.2	No	Yes	25%	Yes	0.766	0.765	0.787	0.777	0.772	0.789	0.793	0.801
31	Crawlspace	4.2	Yes	No		No	0.815	0.766	0.847	0.783	0.819	0.784	0.851	0.799
32	Crawlspace	4.2	Yes	No		Yes	0.815	0.775	0.847	0.793	0.819	0.791	0.851	0.808
33	Crawlspace	4.2	Yes	Yes		No	0.815	0.829	0.847	0.846	0.819	0.848	0.851	0.864
34	Crawlspace	4.2	Yes	Yes		Yes	0.815	0.838	0.847	0.857	0.819	0.855	0.851	0.873
35	Crawlspace	4.2	Yes	Yes	25%	No	0.841	0.847	0.864	0.858	0.845	0.864	0.868	0.875
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.841	0.856	0.864	0.870	0.845	0.872	0.868	0.884
37	Crawlspace	8.0	No	No		No	0.787	0.704	0.804	0.712	0.792	0.727	0.808	0.735
38	Crawlspace	8.0	No	No		Yes	0.787	0.722	0.804	0.731	0.792	0.742	0.808	0.751
39	Crawlspace	8.0	No	Yes		No	0.787	0.761	0.804	0.770	0.792	0.786	0.808	0.794
40	Crawlspace	8.0	No	Yes		Yes	0.787	0.780	0.804	0.791	0.792	0.802	0.808	0.812
41	Crawlspace	8.0	No	Yes	25%	No	0.801	0.770	0.813	0.776	0.805	0.794	0.817	0.800
42	Crawlspace	8.0	No	Yes	25%	Yes	0.801	0.790	0.813	0.797	0.805	0.811	0.817	0.817
43	Crawlspace	8.0	Yes	No		No	0.864	0.800	0.882	0.809	0.867	0.813	0.885	0.822
44	Crawlspace	8.0	Yes	No		Yes	0.864	0.808	0.882	0.818	0.867	0.820	0.885	0.829
45	Crawlspace	8.0	Yes	Yes		No	0.864	0.865	0.882	0.875	0.867	0.879	0.885	0.888
46	Crawlspace	8.0	Yes	Yes		Yes	0.864	0.873	0.882	0.885	0.867	0.886	0.885	0.897
47	Crawlspace	8.0	Yes	Yes	25%	No	0.879	0.876	0.893	0.882	0.882	0.888	0.895	0.895
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.879	0.884	0.893	0.892	0.882	0.896	0.895	0.903
49	DuctsInEx12	4.2	No	No		No	0.829	0.725	0.827	0.721	0.833	0.745	0.832	0.743
50	DuctsInEx12	4.2	No	No		Yes	0.829	0.746	0.827	0.743	0.833	0.763	0.832	0.761
51	DuctsInEx12	4.2	No	Yes		No	0.829	0.784	0.827	0.779	0.833	0.806	0.832	0.803
52	DuctsInEx12	4.2	No	Yes		Yes	0.829	0.806	0.827	0.803	0.833	0.825	0.832	0.823
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.912	0.826	0.910	0.821	0.914	0.836	0.913	0.832
56	DuctsInEx12	4.2	Yes	No		Yes	0.912	0.836	0.910	0.833	0.914	0.844	0.913	0.842
57	DuctsInEx12	4.2	Yes	Yes		No	0.912	0.892	0.910	0.887	0.914	0.903	0.913	0.900
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.912	0.904	0.910	0.900	0.914	0.913	0.913	0.911
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.836	0.732	0.835	0.730	0.840	0.751	0.839	0.750
62	DuctsInEx12	8.0	No	No		Yes	0.836	0.751	0.835	0.750	0.840	0.768	0.839	0.767
63	DuctsInEx12	8.0	No	Yes		No	0.836	0.791	0.835	0.789	0.840	0.812	0.839	0.811
64	DuctsInEx12	8.0	No	Yes		Yes	0.836	0.812	0.835	0.811	0.840	0.830	0.839	0.829
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.920	0.834	0.919	0.831	0.921	0.842	0.921	0.841
68	DuctsInEx12	8.0	Yes	No		Yes	0.920	0.843	0.919	0.841	0.921	0.850	0.921	0.849
69	DuctsInEx12	8.0	Yes	Yes		No	0.920	0.901	0.919	0.898	0.921	0.911	0.921	0.909
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.920	0.911	0.919	0.909	0.921	0.919	0.921	0.918
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 13				Climate Zone 14			
							One Story		Two Story		One Story		Two Story	
Case	Duct Location	Duct R-value	Duct Sealing	Duct Design	Area Reduction	Radiant Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.737	0.667	0.767	0.689	0.709	0.617	0.740	0.642
2	Attic	4.2	No	No		Yes	0.737	0.694	0.767	0.714	0.709	0.654	0.740	0.676
3	Attic	4.2	No	Yes		No	0.737	0.721	0.767	0.745	0.709	0.667	0.740	0.694
4	Attic	4.2	No	Yes		Yes	0.737	0.750	0.767	0.772	0.709	0.707	0.740	0.731
5	Attic	4.2	No	Yes	25%	No	0.762	0.742	0.783	0.759	0.736	0.693	0.758	0.711
6	Attic	4.2	No	Yes	25%	Yes	0.762	0.769	0.783	0.785	0.736	0.729	0.758	0.745
7	Attic	4.2	Yes	No		No	0.811	0.751	0.843	0.776	0.789	0.717	0.824	0.745
8	Attic	4.2	Yes	No		Yes	0.811	0.770	0.843	0.793	0.789	0.744	0.824	0.768
9	Attic	4.2	Yes	Yes		No	0.811	0.812	0.843	0.839	0.789	0.775	0.824	0.805
10	Attic	4.2	Yes	Yes		Yes	0.811	0.833	0.843	0.857	0.789	0.804	0.824	0.830
11	Attic	4.2	Yes	Yes	25%	No	0.838	0.836	0.861	0.854	0.820	0.804	0.844	0.824
12	Attic	4.2	Yes	Yes	25%	Yes	0.838	0.854	0.861	0.871	0.820	0.829	0.844	0.847
13	Attic	8.0	No	No		No	0.783	0.704	0.800	0.717	0.759	0.663	0.778	0.677
14	Attic	8.0	No	No		Yes	0.783	0.727	0.800	0.738	0.759	0.692	0.778	0.705
15	Attic	8.0	No	Yes		No	0.783	0.761	0.800	0.775	0.759	0.716	0.778	0.732
16	Attic	8.0	No	Yes		Yes	0.783	0.785	0.800	0.798	0.759	0.749	0.778	0.762
17	Attic	8.0	No	Yes	25%	No	0.797	0.774	0.810	0.784	0.775	0.731	0.789	0.742
18	Attic	8.0	No	Yes	25%	Yes	0.797	0.797	0.810	0.806	0.775	0.761	0.789	0.771
19	Attic	8.0	Yes	No		No	0.861	0.793	0.880	0.807	0.846	0.768	0.866	0.784
20	Attic	8.0	Yes	No		Yes	0.861	0.807	0.880	0.820	0.846	0.787	0.866	0.801
21	Attic	8.0	Yes	Yes		No	0.861	0.857	0.880	0.873	0.846	0.831	0.866	0.848
22	Attic	8.0	Yes	Yes		Yes	0.861	0.872	0.880	0.886	0.846	0.851	0.866	0.866
23	Attic	8.0	Yes	Yes	25%	No	0.877	0.871	0.891	0.882	0.864	0.848	0.878	0.859
24	Attic	8.0	Yes	Yes	25%	Yes	0.877	0.884	0.891	0.894	0.864	0.865	0.878	0.876
25	Crawlspace	4.2	No	No		No	0.743	0.695	0.772	0.708	0.716	0.647	0.746	0.663
26	Crawlspace	4.2	No	No		Yes	0.743	0.711	0.772	0.726	0.716	0.668	0.746	0.686
27	Crawlspace	4.2	No	Yes		No	0.743	0.751	0.772	0.766	0.716	0.700	0.746	0.717
28	Crawlspace	4.2	No	Yes		Yes	0.743	0.769	0.772	0.785	0.716	0.722	0.746	0.742
29	Crawlspace	4.2	No	Yes	25%	No	0.766	0.766	0.787	0.776	0.742	0.718	0.763	0.729
30	Crawlspace	4.2	No	Yes	25%	Yes	0.766	0.784	0.787	0.795	0.742	0.741	0.763	0.754
31	Crawlspace	4.2	Yes	No		No	0.815	0.780	0.847	0.795	0.796	0.748	0.829	0.766
32	Crawlspace	4.2	Yes	No		Yes	0.815	0.787	0.847	0.804	0.796	0.758	0.829	0.778
33	Crawlspace	4.2	Yes	Yes		No	0.815	0.843	0.847	0.860	0.796	0.809	0.829	0.828
34	Crawlspace	4.2	Yes	Yes		Yes	0.815	0.851	0.847	0.870	0.796	0.819	0.829	0.841
35	Crawlspace	4.2	Yes	Yes	25%	No	0.841	0.860	0.864	0.871	0.825	0.830	0.848	0.842
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.841	0.868	0.864	0.881	0.825	0.840	0.848	0.855
37	Crawlspace	8.0	No	No		No	0.787	0.721	0.804	0.729	0.765	0.681	0.782	0.690
38	Crawlspace	8.0	No	No		Yes	0.787	0.737	0.804	0.746	0.765	0.701	0.782	0.712
39	Crawlspace	8.0	No	Yes		No	0.787	0.780	0.804	0.788	0.765	0.736	0.782	0.746
40	Crawlspace	8.0	No	Yes		Yes	0.787	0.797	0.804	0.807	0.765	0.758	0.782	0.769
41	Crawlspace	8.0	No	Yes	25%	No	0.801	0.788	0.813	0.794	0.780	0.747	0.792	0.753
42	Crawlspace	8.0	No	Yes	25%	Yes	0.801	0.806	0.813	0.813	0.780	0.769	0.792	0.777
43	Crawlspace	8.0	Yes	No		No	0.864	0.810	0.882	0.819	0.850	0.787	0.870	0.797
44	Crawlspace	8.0	Yes	No		Yes	0.864	0.817	0.882	0.827	0.850	0.796	0.870	0.807
45	Crawlspace	8.0	Yes	Yes		No	0.864	0.876	0.882	0.885	0.850	0.850	0.870	0.861
46	Crawlspace	8.0	Yes	Yes		Yes	0.864	0.883	0.882	0.894	0.850	0.860	0.870	0.872
47	Crawlspace	8.0	Yes	Yes	25%	No	0.879	0.885	0.893	0.891	0.867	0.863	0.881	0.869
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.879	0.893	0.893	0.900	0.867	0.872	0.881	0.880
49	DuctsInEx12	4.2	No	No		No	0.829	0.740	0.827	0.737	0.810	0.705	0.807	0.699
50	DuctsInEx12	4.2	No	No		Yes	0.829	0.759	0.827	0.757	0.810	0.728	0.807	0.725
51	DuctsInEx12	4.2	No	Yes		No	0.829	0.800	0.827	0.797	0.810	0.762	0.807	0.756
52	DuctsInEx12	4.2	No	Yes		Yes	0.829	0.820	0.827	0.818	0.810	0.787	0.807	0.783
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.912	0.833	0.910	0.829	0.902	0.815	0.898	0.809
56	DuctsInEx12	4.2	Yes	No		Yes	0.912	0.842	0.910	0.840	0.902	0.827	0.898	0.823
57	DuctsInEx12	4.2	Yes	Yes		No	0.912	0.901	0.910	0.897	0.902	0.882	0.898	0.875
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.912	0.911	0.910	0.908	0.902	0.895	0.898	0.889
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.836	0.746	0.835	0.745	0.818	0.713	0.816	0.710
62	DuctsInEx12	8.0	No	No		Yes	0.836	0.764	0.835	0.763	0.818	0.735	0.816	0.733
63	DuctsInEx12	8.0	No	Yes		No	0.836	0.807	0.835	0.805	0.818	0.771	0.816	0.767
64	DuctsInEx12	8.0	No	Yes		Yes	0.836	0.826	0.835	0.825	0.818	0.795	0.816	0.792
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.920	0.840	0.919	0.838	0.911	0.825	0.909	0.821
68	DuctsInEx12	8.0	Yes	No		Yes	0.920	0.848	0.919	0.847	0.911	0.835	0.909	0.833
69	DuctsInEx12	8.0	Yes	Yes		No	0.920	0.908	0.919	0.906	0.911	0.892	0.909	0.888
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.920	0.917	0.919	0.916	0.911	0.903	0.909	0.900
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

							Climate Zone 15				Climate Zone 16			
	Duct	Duct	Duct	Duct	Area	Radiant	One Story		Two Story		One Story		Two Story	
Case	Location	R-value	Sealing	Design	Reduction	Barrier	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
1	Attic	4.2	No	No		No	0.743	0.596	0.773	0.622	0.686	0.730	0.719	0.755
2	Attic	4.2	No	No		Yes	0.743	0.637	0.773	0.660	0.686	0.740	0.719	0.766
3	Attic	4.2	No	Yes		No	0.743	0.644	0.773	0.672	0.686	0.789	0.719	0.816
4	Attic	4.2	No	Yes		Yes	0.743	0.689	0.773	0.713	0.686	0.801	0.719	0.828
5	Attic	4.2	No	Yes	25%	No	0.767	0.672	0.789	0.690	0.716	0.809	0.739	0.830
6	Attic	4.2	No	Yes	25%	Yes	0.767	0.712	0.789	0.728	0.716	0.820	0.739	0.841
7	Attic	4.2	Yes	No		No	0.815	0.703	0.848	0.731	0.773	0.786	0.809	0.813
8	Attic	4.2	Yes	No		Yes	0.815	0.733	0.848	0.758	0.773	0.792	0.809	0.819
9	Attic	4.2	Yes	Yes		No	0.815	0.760	0.848	0.791	0.773	0.850	0.809	0.879
10	Attic	4.2	Yes	Yes		Yes	0.815	0.793	0.848	0.819	0.773	0.856	0.809	0.886
11	Attic	4.2	Yes	Yes	25%	No	0.842	0.791	0.865	0.811	0.805	0.871	0.831	0.893
12	Attic	4.2	Yes	Yes	25%	Yes	0.842	0.818	0.865	0.836	0.805	0.877	0.831	0.900
13	Attic	8.0	No	No		No	0.788	0.645	0.805	0.660	0.742	0.763	0.761	0.778
14	Attic	8.0	No	No		Yes	0.788	0.678	0.805	0.691	0.742	0.772	0.761	0.787
15	Attic	8.0	No	Yes		No	0.788	0.697	0.805	0.713	0.742	0.825	0.761	0.841
16	Attic	8.0	No	Yes		Yes	0.788	0.733	0.805	0.747	0.742	0.835	0.761	0.851
17	Attic	8.0	No	Yes	25%	No	0.802	0.713	0.814	0.724	0.759	0.837	0.772	0.848
18	Attic	8.0	No	Yes	25%	Yes	0.802	0.746	0.814	0.756	0.759	0.847	0.772	0.859
19	Attic	8.0	Yes	No		No	0.864	0.758	0.883	0.775	0.835	0.822	0.856	0.837
20	Attic	8.0	Yes	No		Yes	0.864	0.779	0.883	0.794	0.835	0.827	0.856	0.843
21	Attic	8.0	Yes	Yes		No	0.864	0.819	0.883	0.837	0.835	0.888	0.856	0.905
22	Attic	8.0	Yes	Yes		Yes	0.864	0.842	0.883	0.858	0.835	0.894	0.856	0.911
23	Attic	8.0	Yes	Yes	25%	No	0.880	0.837	0.893	0.849	0.854	0.901	0.868	0.914
24	Attic	8.0	Yes	Yes	25%	Yes	0.880	0.857	0.893	0.868	0.854	0.906	0.868	0.919
25	Crawlspace	4.2	No	No		No	0.749	0.627	0.777	0.644	0.695	0.762	0.726	0.777
26	Crawlspace	4.2	No	No		Yes	0.749	0.650	0.777	0.669	0.695	0.770	0.726	0.786
27	Crawlspace	4.2	No	Yes		No	0.749	0.678	0.777	0.696	0.695	0.824	0.726	0.840
28	Crawlspace	4.2	No	Yes		Yes	0.749	0.703	0.777	0.723	0.695	0.833	0.726	0.850
29	Crawlspace	4.2	No	Yes	25%	No	0.772	0.698	0.793	0.709	0.723	0.836	0.744	0.848
30	Crawlspace	4.2	No	Yes	25%	Yes	0.772	0.723	0.793	0.737	0.723	0.845	0.744	0.858
31	Crawlspace	4.2	Yes	No		No	0.819	0.735	0.851	0.753	0.780	0.819	0.815	0.835
32	Crawlspace	4.2	Yes	No		Yes	0.819	0.746	0.851	0.767	0.780	0.823	0.815	0.840
33	Crawlspace	4.2	Yes	Yes		No	0.819	0.795	0.851	0.815	0.780	0.885	0.815	0.903
34	Crawlspace	4.2	Yes	Yes		Yes	0.819	0.806	0.851	0.829	0.780	0.890	0.815	0.908
35	Crawlspace	4.2	Yes	Yes	25%	No	0.845	0.817	0.868	0.829	0.811	0.899	0.835	0.911
36	Crawlspace	4.2	Yes	Yes	25%	Yes	0.845	0.829	0.868	0.844	0.811	0.903	0.835	0.917
37	Crawlspace	8.0	No	No		No	0.792	0.664	0.808	0.673	0.747	0.782	0.766	0.791
38	Crawlspace	8.0	No	No		Yes	0.792	0.686	0.808	0.697	0.747	0.790	0.766	0.800
39	Crawlspace	8.0	No	Yes		No	0.792	0.717	0.808	0.728	0.747	0.846	0.766	0.855
40	Crawlspace	8.0	No	Yes		Yes	0.792	0.742	0.808	0.754	0.747	0.855	0.766	0.865
41	Crawlspace	8.0	No	Yes	25%	No	0.805	0.729	0.817	0.735	0.764	0.853	0.776	0.860
42	Crawlspace	8.0	No	Yes	25%	Yes	0.805	0.754	0.817	0.762	0.764	0.862	0.776	0.869
43	Crawlspace	8.0	Yes	No		No	0.867	0.777	0.885	0.787	0.839	0.841	0.859	0.850
44	Crawlspace	8.0	Yes	No		Yes	0.867	0.787	0.885	0.799	0.839	0.845	0.859	0.855
45	Crawlspace	8.0	Yes	Yes		No	0.867	0.840	0.885	0.851	0.839	0.909	0.859	0.919
46	Crawlspace	8.0	Yes	Yes		Yes	0.867	0.851	0.885	0.864	0.839	0.913	0.859	0.924
47	Crawlspace	8.0	Yes	Yes	25%	No	0.882	0.853	0.895	0.860	0.858	0.917	0.871	0.924
48	Crawlspace	8.0	Yes	Yes	25%	Yes	0.882	0.864	0.895	0.872	0.858	0.921	0.871	0.929
49	DuctsInEx12	4.2	No	No		No	0.833	0.689	0.832	0.683	0.795	0.799	0.791	0.800
50	DuctsInEx12	4.2	No	No		Yes	0.833	0.716	0.832	0.711	0.795	0.808	0.791	0.811
51	DuctsInEx12	4.2	No	Yes		No	0.833	0.745	0.832	0.738	0.795	0.863	0.791	0.865
52	DuctsInEx12	4.2	No	Yes		Yes	0.833	0.774	0.832	0.769	0.795	0.873	0.791	0.876
53	DuctsInEx12	4.2	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
54	DuctsInEx12	4.2	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
55	DuctsInEx12	4.2	Yes	No		No	0.914	0.808	0.913	0.800	0.894	0.860	0.889	0.862
56	DuctsInEx12	4.2	Yes	No		Yes	0.914	0.821	0.913	0.816	0.894	0.865	0.889	0.868
57	DuctsInEx12	4.2	Yes	Yes		No	0.914	0.873	0.913	0.865	0.894	0.930	0.889	0.932
58	DuctsInEx12	4.2	Yes	Yes		Yes	0.914	0.888	0.913	0.882	0.894	0.935	0.889	0.938
59	DuctsInEx12	4.2	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
60	DuctsInEx12	4.2	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
61	DuctsInEx12	8.0	No	No		No	0.840	0.698	0.839	0.695	0.804	0.803	0.802	0.804
62	DuctsInEx12	8.0	No	No		Yes	0.840	0.723	0.839	0.720	0.804	0.811	0.802	0.813
63	DuctsInEx12	8.0	No	Yes		No	0.840	0.755	0.839	0.751	0.804	0.868	0.802	0.869
64	DuctsInEx12	8.0	No	Yes		Yes	0.840	0.782	0.839	0.779	0.804	0.877	0.802	0.879
65	DuctsInEx12	8.0	No	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
66	DuctsInEx12	8.0	No	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
67	DuctsInEx12	8.0	Yes	No		No	0.921	0.818	0.921	0.814	0.905	0.865	0.902	0.866
68	DuctsInEx12	8.0	Yes	No		Yes	0.921	0.830	0.921	0.827	0.905	0.869	0.902	0.870
69	DuctsInEx12	8.0	Yes	Yes		No	0.921	0.885	0.921	0.880	0.905	0.935	0.902	0.936
70	DuctsInEx12	8.0	Yes	Yes		Yes	0.921	0.897	0.921	0.894	0.905	0.939	0.902	0.941
71	DuctsInEx12	8.0	Yes	Yes	25%	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
72	DuctsInEx12	8.0	Yes	Yes	25%	Yes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

~~APPENDIXK~~

~~Procedures for Determining Required Refrigerant Charge and Adequate Airflow for Split System Space Cooling Systems without Thermostatic Expansion Valves~~

~~1. Overview~~

~~Failure to maintain proper refrigerant charge or proper airflow across the coil reduces the seasonal energy efficiency for an air conditioner (whether a cooling only air conditioner or a heat pump). In addition, excessive refrigerant charge can cause premature compressor failure, while insufficient refrigerant charge allows compressors to overheat. Very low airflow can result in icing of the coil and compressor failure.~~

~~To help avoid these problems and to provide a compliance credit for correctly installed systems, this appendix describes procedures for determining if a residential split system space cooling system has the required refrigerant charge and adequate airflow across the evaporator coil. The applicability of these procedures have the following limitations:~~

- ~~The procedures detailed in this appendix only apply to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs).~~
- ~~As an alternative to the procedures detailed in this appendix, systems may substitute a TXV installed and confirmed through field verification and diagnostic testing.~~
- ~~The procedures detailed in this appendix do not apply to single packaged systems.~~

~~Note that the procedures detailed in this appendix are intended to be used after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications.~~

~~The installer shall install and charge the air conditioner and heat pump equipment in accordance with the manufacturer's instructions and specifications for the specific model equipment installed. The installer shall certify to the builder, building official and HERS rater that they have followed these instruction and specifications prior to proceeding with the procedures in this appendix.~~

~~For dwelling units with multiple systems, this procedure must be applied to each system separately.~~

~~This appendix defines two procedures, the Standard Charge and Airflow Measurement procedure in Section 2 and the Alternate Charge and Airflow Measurement procedure in Section 3. The Standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the Alternate procedure.~~

~~The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure. Note: Wherever thermocouples appear in this document, thermisters can be used instead with the same requirements applying to thermisters as to thermocouples.~~

~~2. Standard Charge and Airflow Measurement Procedure~~

~~This section specifies the Standard charge and airflow measurement procedure. Under this procedure, required refrigerant charge is calculated using the *Superheat Charging Method* and adequate airflow across the evaporator coil is calculated using the *Temperature Split Method*.~~

~~The Standard procedure detailed in this section shall be completed when the outdoor temperature is 55°F or higher after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. All HERS rater verifications are required to use this Standard procedure.~~

~~2.1 Minimum Qualifications for this Procedure~~

~~Persons carrying out this procedure need to be qualified to perform the following:~~

- ~~Obtain accurate pressure/temperature readings from refrigeration manifold gauges.~~
- ~~Obtain accurate temperature readings from thermometer and thermocouple set up.~~
- ~~Check calibration of refrigerant gauges using a known reference pressure and thermometer/thermocouple set up using a known reference temperature.~~
- ~~Determine best location for temperature measurements in ducting system and on refrigerant lineset.~~
- ~~Calculate the measured superheat and temperature split.~~
- ~~Determine the correct level of superheat and temperature split required, based on the conditions present at the time of the test.~~
- ~~Determine if measured values are reasonable.~~

~~2.2 Instrumentation Specifications~~

~~Instrumentation for the procedures described in this section shall conform to the following specifications.~~

~~2.2.1 Digital Thermometer~~

~~Digital thermometer must have thermocouple compatibility (type K and J) and Celsius or Fahrenheit readout with:~~

- ~~Accuracy: ±(0.1% of reading + 1.3º F)~~
- ~~Resolution: 0.2º F~~

~~2.2.2 Thermocouples~~

~~Measurements require five (5) heavy duty beaded low-mass wire thermocouples and one (1) cotton wick for measuring wet-bulb temperatures.~~

~~2.2.3 Refrigerant Manifold Gauge Set~~

~~A standard multiport refrigerant manifold gauge with an accuracy of plus or minus 3% shall be used.~~

~~2.3 Calibration~~

~~The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.~~

~~2.3.1 Thermometer/Thermocouple Field Calibration Procedure~~

~~Thermometers/thermocouples shall be calibrated monthly to ensure that they are reading accurate temperatures. The following procedure shall be used to check thermometer/thermocouple calibration.~~

~~Step 1.Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.~~

~~Step 2.Insert two thermocouples into the center of the ice bath and attach them to the digital thermometer.~~

~~Step 3.Let the temperatures stabilize. The temperatures shall be 32°F (+/- 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any thermocouples that are off by more than 3°F shall be replaced.~~

~~Step 4.Switch the thermocouples and ensure that the temperatures read on T1 and T2 are still within +/- 1°F of 32°F.~~

~~Step 5.Affix sticker with calibration check date onto thermocouple.~~

~~Step 6.Repeat the process for all thermocouples.~~

~~2.3.2 Refrigerant Gauge Field Check Procedure~~

~~Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration.~~

~~***Step 1.***Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.~~

~~Step 2.Attach a thermocouple to the refrigerant cylinder using duct tape so that there is good contact between the cylinder and the thermocouple.~~

~~Step 3. Insulate the thermocouple connection to the cylinder (closed cell pipe insulation can be taped over the end of the thermocouple to provide the insulation).~~

~~Step 4. Zero the low side compound gauge with all ports open to atmospheric pressure (no hoses attached).~~

~~Step 5. Re-install the hose and attach the low side gauge to the refrigerant cylinder.~~

~~Step 6. Read the temperature of the thermocouple.~~

~~Step 7. Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.~~

~~Step 8. If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration.~~

~~Step 9. Repeat the process in steps 4 through 8 for the high side gauge.~~

~~Step 10. Affix sticker with calibration check date onto refrigerant gauge.~~

~~2.4 Charge and Airflow Measurements~~

~~The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge and adequate airflow as described in the following sections.~~

~~Step 1. Establish a return air dry bulb temperature sufficiently high that the return air dry bulb temperature will be not less than 70°F prior to the measurements at the end of the 15 minute period in step 2.~~

~~Step 2. Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature measurements.~~

~~Step 3. Connect the refrigerant gauge manifold to the suction line service valve.~~

~~Step 4. Attach a thermocouple to the suction line near the suction line service valve. Be sure the sensor is in direct contact with the line and is well insulated from air temperature.~~

~~***Step 5.*** Attach a thermocouple to measure the condenser (entering) air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.~~

~~Step 6. Be sure that all cabinet panels that affect airflow are in place before making measurements. The thermocouple sensors shall remain attached to the system until the final charge is determined.~~

~~Step 7.Place wet-bulb thermocouple in water to ensure it is saturated when needed.~~ **~~Do not get the dry-bulb thermocouples wet.~~**

~~***Step 8.***Insert the dry-bulb thermocouple in the supply plenum at the center of the airflow.~~

~~Step 9.At 12 minutes, insert a dry-bulb thermocouple and a wet-bulb thermocouple into the return plenum at the center of the airflow.~~

~~Step 10.At 15 minutes when the return plenum temperatures have stabilized, using the thermocouples already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return, db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return, wb}$).~~

~~Step 11.Using the dry-bulb thermocouple already in place, measure and record the supply (evaporator leaving) air dry-bulb temperature ($T_{supply, db}$).~~

~~Step 12.Using the refrigerant gauge already attached, measure and record the evaporator saturation temperature ($T_{evaporator, sat}$) from the low side gauge.~~

~~Step 13.Using the dry-bulb thermocouple already in place, measure and record the suction line temperature ($T_{suction, db}$).~~

~~Step 14.Using the dry-bulb thermocouple already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser, db}$).~~

~~The above measurements shall be used to adjust refrigerant charge and airflow as described in following sections.~~

~~2.5 Refrigerant Charge Calculations~~

~~The Superheat Charging Method is used only for non-TXV systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices. The following steps describe the calculations to determine if the system meets the required refrigerant charge using the measurements described in section 2.4. If a system fails, then remedial actions must be taken. If the refrigerant charge is changed and the airflow has been previously tested and shown to pass, then the airflow shall be re-tested. Be sure to complete Steps 1 and 2 of Section 2.4 before re-testing the airflow. Both the airflow and charge must be re-tested until they both sequentially pass.~~

~~Step 1.Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.~~
~~Actual Superheat = $T_{suction, db}$ – $T_{evaporator, sat}$.~~

~~Step 2.Determine the Target Superheat using Table K-1 using the return air wet-bulb temperature ($T_{return, wb}$) and condenser air dry-bulb temperature ($T_{condenser, db}$).~~

~~Step 3.If a dash mark is read from Table K-1, the target superheat is less than 5°F, then the system~~ ~~**does not pass**~~ ~~the required refrigerant charge criteria, usually because outdoor conditions are too hot and dry. One of the following adjustments is needed until a target superheat value can be obtained from Table K-1 by either 1) turning on the space heating system and/or opening the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. After adjustments, repeat the measurement procedure as often as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before completing the measurement procedure again.~~

~~Step 4.Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat)~~

~~Step 5.If the difference is between minus 5 and plus 5°F, then the system~~ ~~**passes**~~ ~~the required refrigerant charge criteria.~~

~~Step 6.If the difference is greater than plus 5°F, then the system~~ ~~**does not pass**~~ ~~the required refrigerant charge criteria and the installer shall add refrigerant. After the refrigerant has been added, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement procedure as many times as necessary to pass the test.~~

~~Step 7.If the difference is between -5 and -100°F, then the system~~ ~~**does not pass**~~ ~~the required refrigerant charge criteria, the installer shall remove refrigerant. After the refrigerant has been removed, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement as many times as necessary to pass the test.~~

~~Table K-1: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)~~

Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1

~~Table K-1: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature) (continued)~~

		Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
	92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
	93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
	95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
	97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
	101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
	102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
	103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
	104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
	106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
	107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
	108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
	109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
	111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
	113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
	114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
	115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

~~2.6 Adequate Airflow Calculations~~

~~The temperature split method is designed to provide an efficient check to see if airflow is above the required minimum. The following steps describe the calculations using the measurement procedure described in section 2.4. If a system fails, then remedial actions must be taken. If the airflow is changed and the refrigerant charge has previously been tested and shown to pass, then the refrigerant charge shall be re-tested. Be sure to complete Steps 1 and 2 of Section 2.4 before re-testing the refrigerant charge. Both the airflow and charge must be re-tested until they both sequentially pass.~~

~~Step 1.Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split =~~ $\cancel{T_{return, db} - T_{supply, db}}$

~~Step 2.Determine the Target Temperature Split from Table K-2 using the return air wet-bulb temperature (~~$\cancel{T_{return, wb}}$~~) and return air dry-bulb temperature (~~$\cancel{T_{return, db}}$~~).~~

~~Step 3. If a dash mark is read from Table K-2, then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section 3.4 below.~~

~~Step 4.Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split). If the difference is within plus 3°F and minus 3°F, then the system **passes** the adequate airflow criteria.~~

~~Step 5.If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure as often as necessary to establish adequate airflow range. Allow system to stabilize for 15 minutes before repeating measurement procedure.~~

~~Step 6.If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow.~~

~~Step 7.If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).~~

~~Table K-2: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)~~

Return Air Dry-Bulb (ºF) ($T_{return, db}$)	Return Air Wet-Bulb (ºF) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

~~3. Alternate Charge and Airflow Measurement Procedure~~

~~This section specifies the Alternate charge and airflow measurement procedure. Under this procedure, the required refrigerant charge is calculated using the *Weigh-In Charging Method* and adequate airflow across the evaporator coil is calculated using the *Measured Airflow Method*.~~

~~HVAC installers who must complete system installation verification when the outdoor temperature is below 55°F shall use this Alternate procedure in conjunction with installing and charging the system in accordance with the manufacturer's specifications. HERS Raters shall not use this procedure to verify compliance.~~

~~Split system air conditioners come from the factory already charged with the standard charge indicated on the name plate. The manufacturer supplies the charge proper for the application based on their standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line length different from the manufacturer's standard.~~

~~3.1 Minimum Qualifications for this Procedure~~

~~HVAC installation technicians need to be qualified to perform the following:~~

- ~~Transfer and recovery of refrigerant (including a valid Environmental Protection Agency (EPA) certification for transition and recovery of refrigerant).~~
- ~~Accurately weigh the amount of refrigerant added or removed using an electronic scale.~~
- ~~Calculate the refrigerant charge adjustment needed to compensate for non-standard lineset lengths/diameters based on the actual lineset length/diameter and the manufacturer's specifications for adjusting refrigerant charge for non-standard lineset lengths/diameters.~~

~~3.2 Instrumentation Specifications~~

~~Instrumentation for the procedures described in this section shall conform to the following specifications.~~

~~3.2.1 Digital Charging Scale~~

~~The digital scale used to weigh in refrigerant must have a range of .5 oz to at least 1200 oz (75 lb.). The scale's accuracy must be ± 0.25 oz.~~

~~3.3 Weigh-In Method~~

~~The following procedure shall be used by the HVAC installer to charge the system with the correct refrigerant charge.~~

~~Step 1.Obtain manufacturer's standard liquid line length and charge adjustment for alternate liquid line lengths.~~

~~Step 2.Measure and record the actual liquid line length (L_{actual}).~~

~~Step 3.Record the manufacturer's standard liquid line length ($L_{standard}$).~~

~~Step 4.Calculate the difference between actual and standard liquid line lengths ($L_{actual} – L_{standard}$).~~

~~Step 5.Record the manufacturer's adjustment for liquid line length difference per foot (A_{length}).~~

~~Step 6.Calculate the amount of refrigerant to add or remove and document the calculations on the CF-6R.~~

~~Step 7.Weigh in or remove the correct amount of refrigerant~~

~~3.4 Airflow Measurement~~

~~The airflow across the indoor evaporator coil shall be measured using one of the 2 methods described Appendix F - Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems:~~

~~Section 4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood~~

~~Section 4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching~~

~~3.5 Adequate Airflow Calculation~~

~~The measured airflow method is used to provide a check to see if airflow is above the required minimum of 385 CFM per nominal ton of capacity (assumes coil is dry). The following steps describe the calculations using the measurement procedure described in Section 3.4. If a system fails, then remedial actions must be taken. The airflow must be re-tested until it passes.~~

~~Step 1.Record the measured airflow ($F_{measured}$) obtained from the measurement procedures described in Section 3.4.~~

~~Step 2.Obtain and record the rated cooling capacity ($C_{cooling}$) in Btu.~~

~~Step 3.Calculate the required airflow as the product of the rated cooling capacity in Btu times 0.032.~~

~~Step 4.Compare the airflow measured according to section 3.4 with the required airflow.~~

~~Step 5.If the measured airflow is greater than the required airflow, then the system **passes** the adequate airflow criteria.~~

Step 6.~~If the measured airflow is less than the required airflow, the system does not pass the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure.~~